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Bedford, MA

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ENVIRONMENTAL ASSESSMENT: SOURCE TEST AND EVALUATION REPORT - B&W/ALLIANCE ATMOSPHERIC FLUIDIZED-BED COMBUSTOR

Final Report

April 1981

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16. ABSTRACT The report gives results of a comprehensive emission sampling and analysis of a pilot-scale, atmospheric-pressure, coal-fired, fluidized-bed combustor (AFBC). Screening data on organic and inorganic pollutants and indications of biological activity were obtained. The Babcock and Wilcox/Electric Power Research Institute AFBC at Alliance, OH (B and W/EPRI/Alliance), with a coal-firing capacity of 880 kg/hr was tested. Air pollutant emissions of trace elements were measured upstream of particulate controls. Assuming a control efficiency of 99.9%, necessary to meet the utility boiler Federal NSPS for particulate of 13 ng/J, emissions of trace elements are not significant. Elemental concentrations do not appear to be significantly different from other FBCs or conventional coal combustion systems. Limited further analyses for specific polynuclear aromatic compounds indicate that emissions of these compounds are probably of no concern. Analysis of laboratory-generated leachates from solid waste samples reveals that trace metal concentrations are well below Federal hazardous waste criteria. Positive test results for mutagenicity and cytotoxicity screening tests require further investigation.

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SECTION 1

SUMMARY AND CONCLUSIONS
B&W/ALLIANCE AFBC SOURCE TEST AND EVALUATION

The Babcock and Wilcox/Electric Power Research Institute facility at Alliance, Ohio consists of a 2.4 MW atmospheric fluidized-bed combustor (AFBC) designed as an intermediate-scale test and development unit. Six process and emission streams were sampled for Level 1 chemical and biological analysis in December 1979. These stream samples included: combustor flue gas, gaseous components and entrained solids, sampled by GCA; solids collected by the final particulate control device (baghouse), sampled by B&W; solids collected by the primary dust collector (cyclones), sampled by B&W; spent combustion bed solids, sampled by B&W; coal and sorbent feed streams, sampled by B&W. Although baghouse catch was sampled by B&W personnel, this sample was not released by EPRI and B&W for analysis so no data are available for this stream sample. Because the baghouse had only recently been installed, ports to sample flue gases after the baghouse were not available. The sampling procedures employed and the handling of samples were those methods specified in the IERL-RTP Level 1 Procedures Manual.

RESULTS

Test results are presented on a stream-by-stream basis and address data in terms of inorganic analysis, organic analysis and biological activity. Following summation of test results for each stream sample, prioritization of streams for Level 2 analysis is discussed. Results are summarized in Table 1.

COMBUSTOR FLUE GAS

Inorganic chemical analysis of the flue gas stream involves quantification of trace elements in Source Assessment Sampling System (SASS train) component samples using spark source mass spectrometry (SSMS) and atomic absorption spectroscopy (AA). Trace elemental concentrations in flue gas were evaluated in two ways. Data were incorporated into Source Analysis Model IA (SAM/IA) and compared with relevent Discharge Multimedia Environmental Goals (DMEGs). Discharge Severity (DS) was calculated for each, and those elements exceeding their emission goals (DS > 1.0) were "flagged" as potential candidates for further investigation.

Comparison of trace elemental concentrations in the combustor flue gas stream with air DMEGs resulted in twenty-five species in excess of their emission goals. These results require careful interpretation, however, because combustor flue gas was sampled prior to any particulate control devices. An evaluation of these data should be made by assuming particulate control operating

TABLE 1. SUMMARY OF B&W/ALLIANCE SOURCE TEST AND EVALUATION RESULTS

Stream Description	Inorganic Results	Organic Results	Bioassay Results
Combustor flue gas	Twenty-five trace elements exceeded their air emission goals in uncontrolled combustor flue gas. If particulate control sufficient to meet the NSPS for particles from Utility Boilers is assumed (99.9 percent control to meet 0.03 lb/10^6 Btu) only two elements, chromium and vanadium, exceed air DMEGs.	Based on "worst-case" analysis, twelve organic compounds could be present. Of these, several PNA species including B(a)P and 1,2:5,6-dibenzanthracene are of special concern.	Combustor flue gas samples were tested using the health effects assays only. XAD-extract exhibited positive mutagenicity in the Ames test and high toxic response in CHO. Flue gas particles were negative in the Ames and showed low to moderate response to RAM cells depending on particle size.
Bulk solid waste streams			
Combustor cyclone catch	Fifteen trace elements exceeded land DMEGs.	Organic content of both solid waste streams was extremely low so no compounds of concern are evident.	Both streams exhibited low toxic response to RAM and CHO cells; both were negative in the Ames test.
Spent bed material	Ten trace elements exceeded land DMEGs		
Combustor cyclone catch-leachate	Five trace elements exceeded water DMEGs.	Not applicable.	Both leachates exhibited high toxicity in all three ecological effects tests. Data indicated toxicity was due to elevated pH, similar to results from other tests run on FBC leachates.
Spent bed material-leachate	Four trace elements exceeded water DMEGs.		
	Data for both leachates were compared to OSW criteria for identification of hazardous waste; levels of trace elements were well below OSW criteria for both streams.		
Feed streams			
Coal	Six trace elements exceeded land DMEGs.	No data analysis performed.	Not tested.
Sorbent	Eight trace elements exceeded land DMEGs.		

at a level sufficient to meet particulate New Source Performance Standards (NSPS) for Utility Boilers. Of the particles in the flue gas stream, 99.9 percent would have to be removed to meet the current NSPS of 0.03 lb particles/ 10^6 Btu. This collection efficiency is within the capability of conventional particulate control devices. If this level of efficiency is assumed, only two trace elements would exceed air DMEGs. Chromium exceeds its health goal and vanadium its ecological goal. It must be mentioned, however, that evaluation of these data in this manner is an oversimplification and ignores the possible effects of varying particle sizes, potential concentration of some species on particles of smaller diameter, etc.

Level 1 organic analytical data from components of combustor flue gas was evaluated to permit estimation of the presence of organic compounds or families of compounds of potential concern. This evaluation was accomplished on a "worst-case" basis by assuming that the entire organic content of the sample under study represented the most hazardous species potentially present in the boiling-point range representative of that fraction. This analysis was performed over the complete boiling point range of interest including low boiling materials (Gaseous-measured by on-site gas chromatography(GC)), intermediate compounds (Total Chromatographable Organics (TCO)) and the heavier, higher boiling compounds (Gravimetric (GRAV)). TCO and GRAV data were also evaluated for each fraction following the required Liquid Chromatographic (LC) separation of the XAD-CH_2Cl_2 extract. Evaluation of organic data revealed the potential presence of twelve compounds or compound classes of concern including a number of polynuclear aromatic hydrocarbons (PNAs).

Combustor flue gas components were tested for biological activity using the health effects tests which make up part of the Level 1 battery of short-term bioassays. Flue gas particles were not mutagenic in the Ames test but did exhibit a positive toxic response to rabbit alveolar macrophages. Fine particles were moderately toxic while coarse particles had a low toxic response.

XAD-extract had a positive mutagenic response in three of the Salmonella tester strains. Specific activity was 8 revertants/µg organics at the lowest recorded positive dose which is similar to the activity observed for Exxon Miniplant XAD-extract from combustor flue gas. Also, similar to Exxon results, addition of S-9 activation mix resulted in a lower mutagenic activity. Therefore, PNA species, which require microsomal activation for positive Ames response, could not be solely responsible for the observed mutagenicity. XAD-extract also exhibited a positive toxic response to Chinese hamster ovary (CHO) cells.

These results are similar to those observed in testing samples from other combustion systems.

BULK SOLIDS

B&W/Alliance bulk solid streams inorganic data were evaluated in two ways. Trace elemental concentrations in solid waste (cyclone catch and spent bed material) streams and feed (coal and limestone) streams were compared to land DMEGs. In addition, distilled-water leachates of the solid waste streams were generated in the laboratory, analyzed, and results were compared to water DMEGs.

Feed Streams

Six and eight trace elements exceeded land DMEGs in coal and sorbent samples, respectively. Although coal was analyzed for organic content (TCO & GRAV) and totals exceeded the Level 1 criteria for LC fractionation, no fractionation was run. Sorbent was not analyzed for organic content. Neither stream sample was bioassayed.

Bulk Solid Waste Streams

Fifteen elements in cyclone ash and ten in spent bed material were in excess of land DMEGs. Leachates of these samples had concentration of five and four elements, respectively, in excess of water DMEGs. Trace element concentrations in both leachates were compared to EPA - Office of Solid Waste (OSW) criteria which identify hazardous solid waste. Concentration of trace elements in these leachates was well below OSW limits.

Organic content of these streams was negligible. Cytotoxicity of the solids tested was low in all assays run. Although testing of leachates in ecological effects assays resulted in uniformily high toxic response in all tests for both leachate samples, these results are of limited use. Similar to results from testing of Exxon PFBC leachate samples, the high toxicity was a result of increases in pH, to levels fatal to the test species. Although increased pH is a valid endpoint to be measured in these tests, toxicity due to increased pH masks effects which could be due to chemical constituents of these leachate samples.

IMPLICATIONS OF LEVEL 1 DATA FOR LEVEL 2 ANALYSIS

The goal of Level 1 analysis is accumulation of sufficient test data to enable ranking the process or emissions streams under study for intensive, more compound-specific (Level 2) analysis. Based on Level 1 results, as summarized above, B&W/Alliance stream samples were ranked as follows:

High priority:	Combustor flue gas XAD-extract
	Combustor flue gas fine particles
	Combustor flue gas coarse particles
Low priority:	Combustor cyclone catch-leachate
	Spent combustion bed material-leachate
No further analyses planned:	Coal feed
	Sorbent feed

LIMITED LEVEL 2 CHEMICAL ANALYSIS

As an initial Level 2 investigative effort, combustor flue gas SASS-train component samples, both XAD-extract and particles, as well as the cyclone hopper catch were screened for PNA content using high performance liquid

chromatography (HPLC) with fluorescence detection. This procedure was selected to provide compound-specific information in a cost-effective manner.

Results indicated that 1, 2, 5, 6 dibenzanthacene could be present in SASS fine particles in concentrations high enough to warrant further investigation.

CONCLUSIONS AND RECOMMENDATIONS

Air emissions of trace elements from the B&W-EPRI/Alliance AFBC are probably not a significant environmental concern according to available emission goals. However, this judgment is partly based on particulate measurements which were made before the use of any control device and to which a "control factor" of 99.9 percent was applied. Measurements after a final particulate control device should be conducted to confirm that 99.9 percent control can be achieved.

Emissions of organic compounds appear not to be a significant problem. Bioassay testing produced results similar to those reported for other combustion processes. However, the positive mutagenicity and cytotoxicity results require some further investigation. Both additional bioassays and chemical analyses should be conducted in an effort to identify those compounds responsible for the observed biological activity.

SECTION 2

DESCRIPTION OF THE FACILITY

The Babcock and Wilcox Alliance, Ohio, facility consists of a 2.4 MW atmospheric fluidized-bed combustor (AFBC) with a bed size of 1.8 x 1.8 meters designed as an intermediate-scale test development unit. This unit has been previously described.[2] The major components of the unit are depicted schematically in Figure 1.

UNIT OPERATIONS

Crushed, pre-sized coal and limestone are fed from separate storage bunkers into the common transport system. Feed rates are controlled by variable rate screw feeders. The coal/limestone feed mixture is transported pneumatically to a splitter where the feed stream is equally split into four separate lines. These four lines carry the coal and limestone into the combustion zone of the unit. The combustion bed consists of four equal 0.9 x 0.9 meter quadrants and one feed line discharges into the center of each. The resultant feedpoint/area ratio provides even distribution of fuel sorbent across the entire bed.

The furnace enclosure of the unit consists of an atmospheric pressure water wall with a fireside refractory lining. Total height of the facility is 14.6 meters. Combustion air enters the plenum and is forced through the distributor plate and into the bed. During operation, the bed depth is maintained between 1.4 and 2.0 meters and is cooled by a serpentine arrangement of eleven 3.8cm tubes on a 7.6cm triangular pitch. This in-bed tube bank keeps the bed temperature between 780 and 870°C. A convective tube bank in the freeboard cools the combustor flue gas to below 480°C. The distance from the top of the expanded bed to the convective tube bank is approximately 6 meters. This high freeboard improves combustion efficiency while reducing the dust loading on the primary dust collector.

Particulate laden flue gas exits the combustor at the top and splits into four streams in the primary dust collector. The four cyclone separators in the primary dust collector are mounted in parallel and discharge into a single hopper. Individual dampers on each cyclone permit inlet velocity control for maintenance of high cyclone efficiency. Collected material is dumped into 55-gallon drums on a continuous basis and subsequently disposed of. Although the facility has the potential for recycling this material to the combustor, recycle was not run during this program.

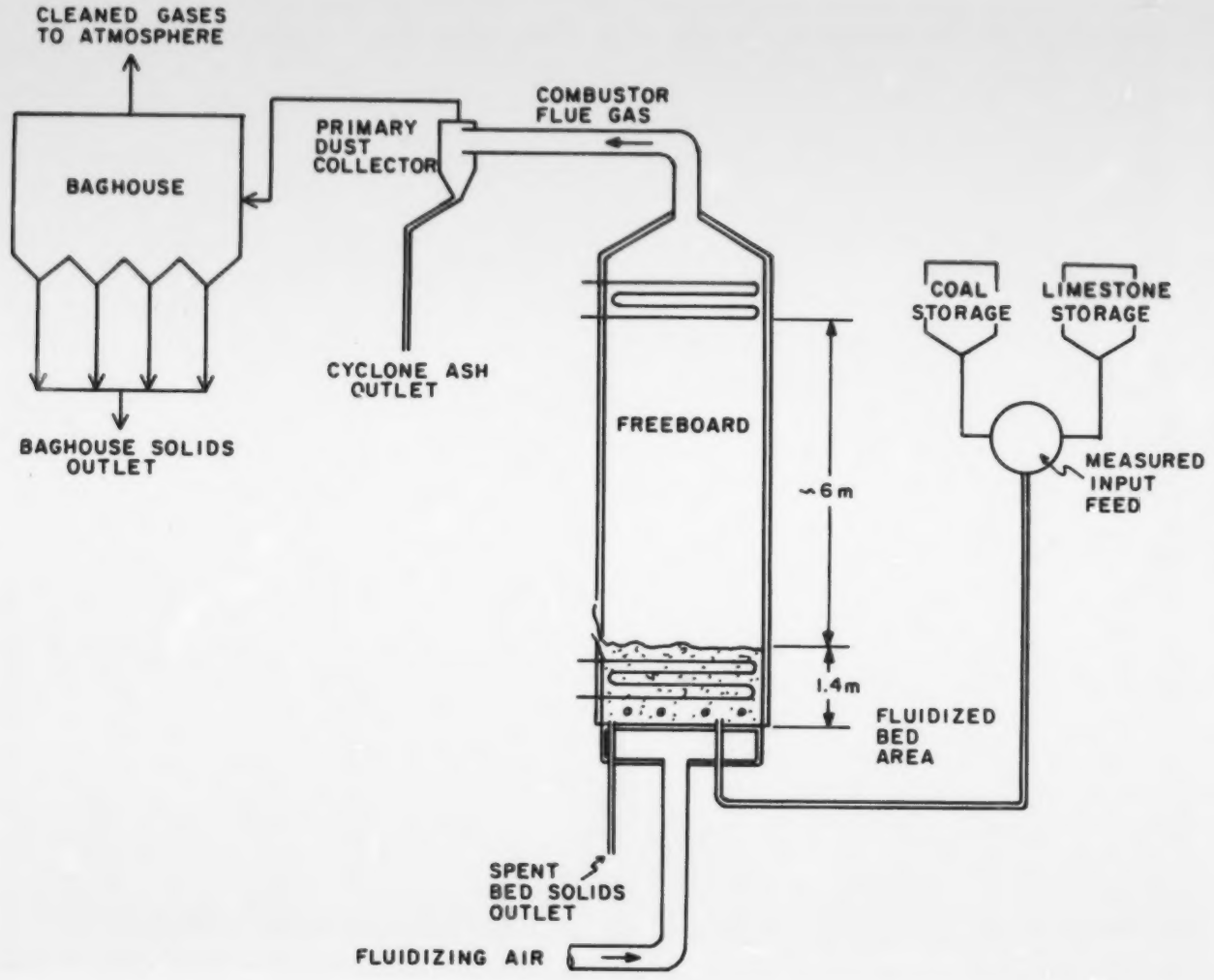

Figure 1. Simplified drawing of the B&W/Alliance AFBC.

The flue gas leaving the cyclones passes through a venturi flowmeter and is then spray-quenched prior to entering the baghouse for final particulate removal. The baghouse is a four-cell unit with a design air/cloth ratio of 4. Ash collected in the baghouse is discharged into a collection bin for disposal. The particulate-free flue gas is then discharged to the atmosphere.

Spent bed solids are removed from the combustor via five drain pipes which extend down from the bed through the distribution plate and plenum and discharge into a water-cooled screw conveyer. Bed height and, therefore, rate of spent bed material removal is controlled by measurement of the pressure drop across the bed.

OPERATING CONDITIONS

Comprehensive emissions testing at the B&W/Alliance AFBC facility was conducted from December 10, 1979 to December 14, 1979. The system had operated at steady state for several days prior to testing to ensure stable bed conditions. Operating conditions including mass flow rates for input and output streams are presented as daily averages in Table 2.

TABLE 2. OPERATING CONDITIONS DURING THE B&W/ALLIANCE AFBC TEST PROGRAM

Parameter	12/10	12/12	12/13	12/14
Pressure, kPa (atm)	101 (1)	101 (1)	101 (1)	101 (1)
Bed temperature, °C	840° (1550°)	840° (1550°)	840° (1550°)	840° (1550°)
Bed height, m (ft)	1.4 (4)	1.4 (4)	1.4 (4)	1.4 (4)
Coal type	Pittsburgh No. 8, 2.4 percent S, 12,500 Btu/lb			
Coal feed rate, kg/hr (lb/hr)	872 (1920)	878 (1935)	890 (1960)	881 (1940)
Sorbent type	Lowellville limestone			
Sorbent feed rate, kg/hr (lb/hr)	204 (450)	272 (600)	272 (600)	272 (600)
Coal and sorbent size	1/4 x 0 and 5/16 x 0, respectively			
Ca/S ratio	2.58	3.37	3.37	3.37
Spent bed material, kg/hr (lb/hr)	78 (172)	100 (220)	118 (261)	88 (193)
Cyclone catch, kg/hr (lb/hr)	170 (375)	171 (376)	163 (358)	216 (475)
Baghouse catch, kg/hr (lb/hr)	80 (176)	93 (203)	92 (202)	86 (190)

SECTION 3

SAMPLING TECHNIQUES

Six streams were sampled for Level 1 chemical and biological testing at the B&W/Alliance AFBC. Sampling points are illustrated in Figure 2, and the streams samples are listed and described in Table 3. The program included sampling the flue gas stream and five solid streams. Sampling procedures employed and handling of samples following the test program were those methods specified in the Level 1 Procedures Manual.[1]

SAMPLING OF THE B&W/ALLIANCE COMBUSTOR FLUE GAS STREAM

A summary of methods used to obtain representative samples for quantification of chemical species in the flue gas stream at the B&W/Alliance AFBC is presented in Table 4. The Source Assessment Sampling (SASS train) was used to collect size-fractionated particles and volatile organic and trace metal components of the Alliance fule gas stream for subsequent physical, chemical, and biological testing.

The SASS train (depicted in Figure 3) collects particles in a series of three cyclones with nominal cut points of 10 μm, 3 μm, and 1 μm. A 150 mm filter collects those particles less than 1 μm. Volatile organic species were captured by 150 g of XAD-2 resin contained in a temperature-controlled trap. A series of impingers follow the resin trap to capture volatile trace metal species (Hg, As, and Sb). Setup and performance of the SASS train followed Level 1 specifications.[1] SASS train sampling was conducted using a 5-inch sampling port located on a 20-inch diameter horizontal duct located between the boiler outlet and the primary dust collector.* The port was approximately 10 diameters downstream of the boiler outlet and 12 diameters upstream of the cyclone inlet. This same port was subsequently used for the Goksoyr-Ross controlled condensation train as well as for obtaining grab samples and integrated bag samples.

During sampling, the SASS probe nozzle was positioned in the duct at a fixed point of average velocity determined by a preliminary velocity traverse in accordance with EPA Method 2. A modification to the standard SASS methodology was the use of an air-cooled probe to lower sample gas temperature from 450°C to approximately 200°C. Two complete SASS-train runs were completed. The sample volume on December 10, 1979 (day 1) was 26.28 dscm/ 28.23 dscm were sampled on December 12, 1979 (day 2). Both runs were slightly below the 30.0 dscm which is designated to be sampled for a normal Level 1 test run.

*Note: During the time of our testing, sampling ports had not yet been installed on the baghouse outlet, so only uncontrolled emissions were sampled.

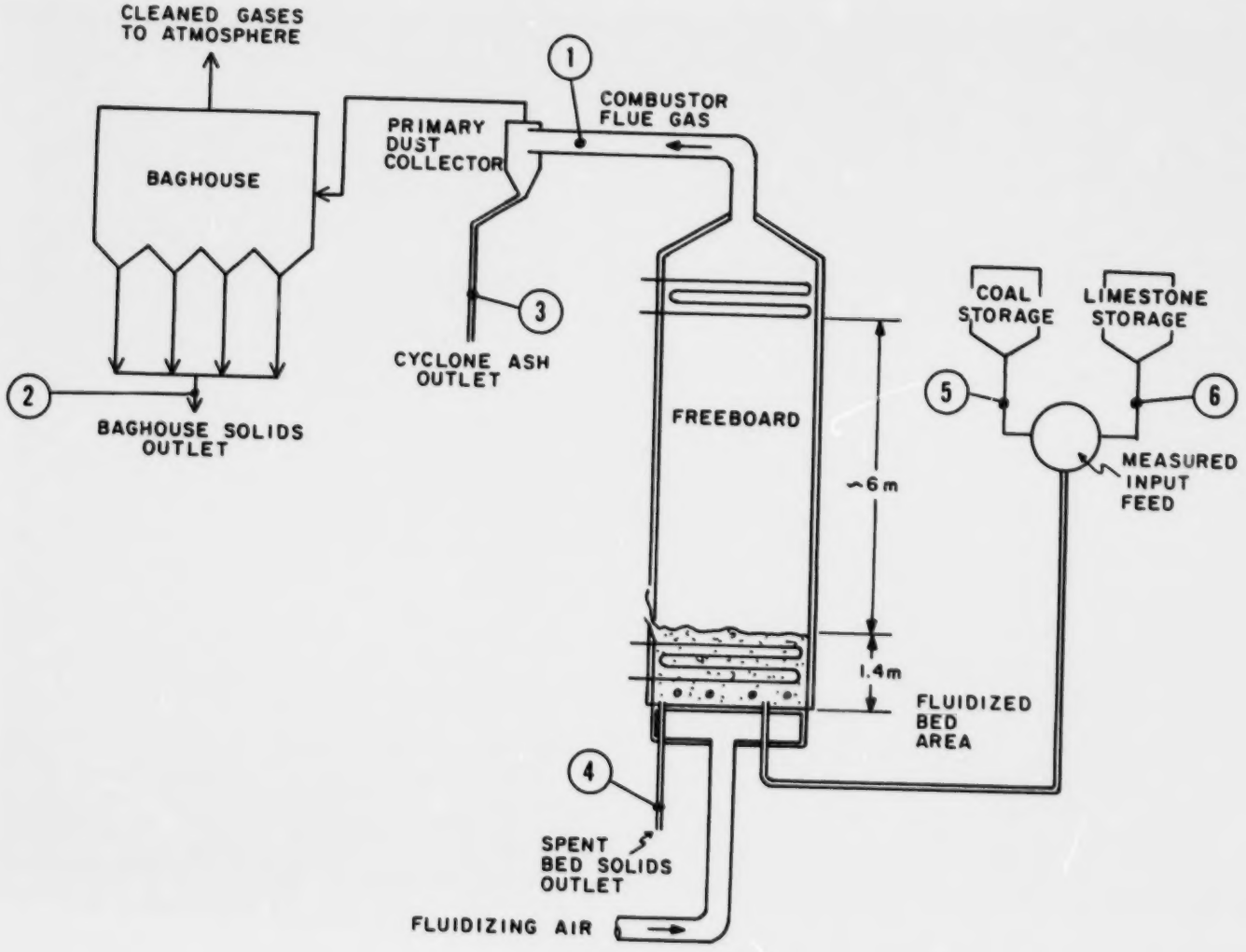

Figure 2. Simplified drawing of the B&W/Alliance AFBC indicating relative Level 1 sampling points.

TABLE 3. SUMMARY OF B&W/ALLIANCE AFBC STREAM SAMPLES

Sample point[a] (ID number)	Stream description	Physical state	Sampled by	Important characteristics
1 (BW1-1-01, BW1-2-01)[b]	Combustor flue gas	Gas and solids	GCA	Fly ash entrained in combustion gases, particle concentration about 35 g/Nm^3. Temperature approximately 450°C (900°F), pressure 100 kPa (1 atm)
2 (BW1-1-02)	Solids collected by the final control device (baghouse)	Solid	B&W	Stream contains fly ash, temperature 200°C (400°F)
3 (BW1-1-03)	Solids collected by the primary dust collector (cyclones)	Solid	B&W	Stream contains fly ash, temperature is approximately 450°C (900°F)
4 (BW1-1-04)	Spent combustion bed solids	Solid	B&W	Solids stream containing spent sorbent and some bottom ash, discharge temperature approximately 800°C (1550°F)
5 (BW1-1-05)	Coal feed	Solid	B&W	No special characteristics
6 (BW1-1-06)	Sorbent feed	Solid	B&W	No special characteristics

[a]Refer to Figure 2.

[b]Two complete SASS runs were performed.

TABLE 4. SUMMARY OF SAMPLING OF B&W/ALLIANCE FLUE GAS STREAM

Species quantified	Sampling method employed	Comments
Fixed gases		
CO	Integrated bag sample	Analyzed on-site by Kitagawa tube
CO	B&W on-line continuous monitor	Beckman 865 (NDIR)
CO_2	Integrated bag sample	Analyzed on-site by GC (TCD)
CO_2	B&W on-line continuous monitor	Beckman 865 (NDIR) and 7003 (Amperometric)
O_2	Integrated bag sample	Analyzed on-site by GC (TCD)
N_2	Integrated bag sample	Analyzed on-site by GC (TCD)
Sulfur		
SO_2	Evacuated glass bulb	Analyzed on-site by GC (FPD)
SO_2	B&W on-line continuous monitor	Beckman 865 (NDIR)
$SO_4/SO_3/SO_2$	Goksoyr-Ross impingers	Refrigerated (4°C) and shipped to GCA lab for analysis
H_2S	Evacuated glass bulb	Analyzed on-site by GC (FPD)
COS	Evacuated glass bulb	Analyzed on-site by GC (FPD)
MMC	Evacuated glass bulb	Analyzed on-site by GC (FPD)
Nitrogen		
NO_x	EPA Method 7 train	
NO_x	B&W on-line continuous monitor	Beckman 951 (chemiluminescence)
NH_3	Special impinger train	Refrigerated (4°C) and shipped to GCA lab for analysis
HCN	Special impinger train	Analyzed on-site by Hach kit

(continued)

TABLE 4 (continued).

Species quantified	Sampling method employed	Comments
Inorganics		
Trace elements	SASS train components	SASS Cyclone catch; impingers for Hg, As, Sb
HCl	Special impinger train	
HF	Special impinger train	
Organics		
GC1-GC7	Integrated bag sample	Boiling point range -160 to 100°C, analyzed on-site by GC (FID)
Volatile organics	SASS train components	XAD-2 resin module
Nonvolatile organics	SASS train components	
Particles		
Sizing	SASS train components	Cyclone catch
Total	SASS train components	Cyclone catch

NDIR = nondispersive infrared
GC = gas chromatography
TCD = thermal conductivity detector
FPD = flame photometric detector
FID = flame ionization detector
MMC = methyl mercaptan

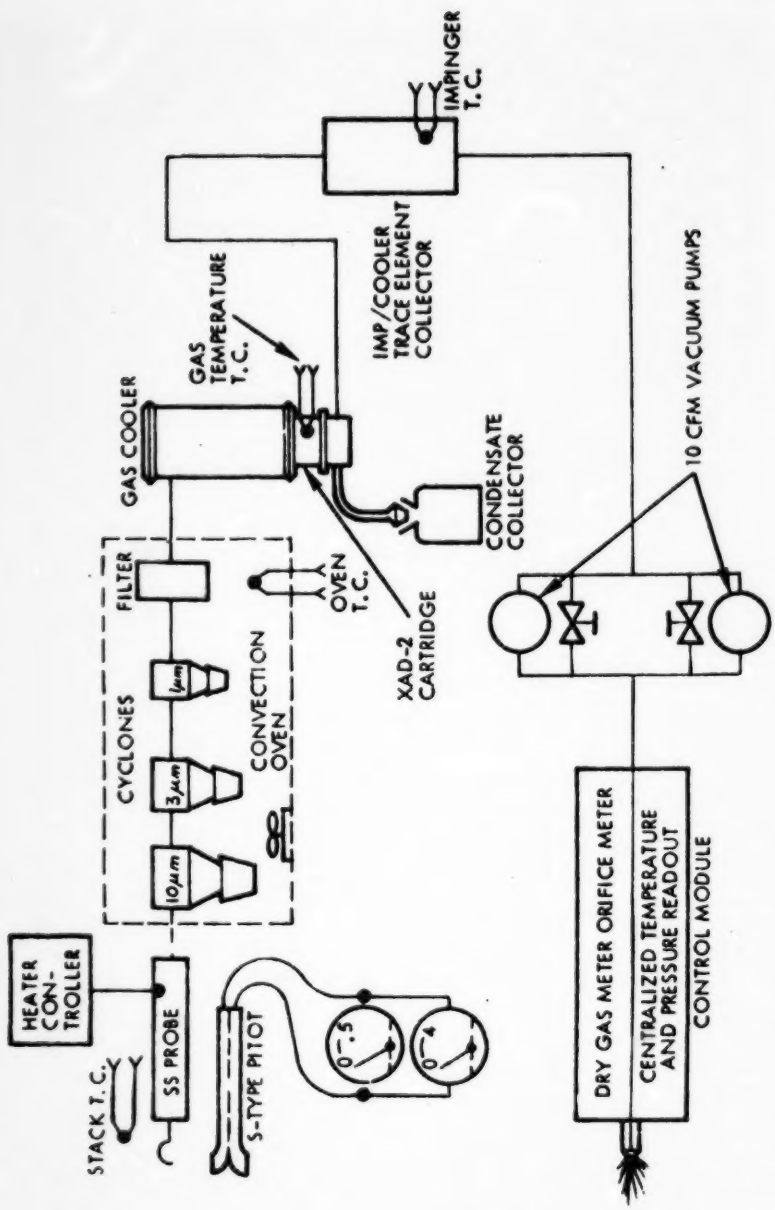

Figure 3. Source assessment sampling train schematic.

Gaseous components of the B&W/Alliance flue gas stream were sampled for subsequent analysis using a combination of continuous withdrawal, grab sampling, and special impinger train techniques.

Fixed Gases

Stack gases were continuously withdrawn through a heated filter and a heated Teflon line and analyzed by B&W on-line continuous monitors for CO, CO_2, NO_x, SO_2, and O_2. These monitors were used in addition to standard Level 1 procedures; samples of CO, CO_2, O_2 and N_2 were obtained as integrated tedlar bag samples and analyzed onsite by gas chromatography (GC). Levels of CO were determined to be below the detection limit of the GC. Therefore, this species was analyzed by Kitagawa detector tubes. Sampling of SO_2 and NO_x is described below.

Sulfur Species

SO_2, H_2S, COS and MMC were quantified in flue gas samples by onsite GC analysis of grab samples obtained in evacuated glass sampling bulbs. The sampling port which was used for the SASS train probe was also used for sampling combustor flue gas for sulfur species. A ¼-in. I.D. by 24-in. 316 SS sampling probe was inserted to the middle of the duct, with a 36-in. by ¼-in. I.D. teflon line connected to the sampling probe leading to a 2-liter glass sampling bulb. The sampling bulb was purged with ten times its volume of flue gas prior to collecting each sample.

The glass sampling bulb was first wrapped with heating tape and then wrapped with insulating tape for protection from degradation and breakage. However, degradation of SO_2 grab samples was recognized on 12/12/79. This degradation was apparently due to the grab sample gas temperature going below the dewpoint of H_2SO_4 (180°F) and possibly reacting with moisture in the flue gas sample. This was corrected by using a variable autotransformer to maintain heat during analysis.

Nitrogen Species

Sampling for ammonia and cyanide was performed with separate wet chemical trains designed to specifically collect each species (see Figure 4). Each train consisted of four glass impingers: the first two containing 150 milliliters each of absorbing solution, the third empty and the fourth, approximately 200 grams of silica gel. The impinger train was preceded by a heated glass cyclone and 4-in. glass-fiber filter. The cyclone and filter were necessary for particulate material removal, as high particulate concentrations would interfere with the colorimetric analysis of the absorbing solutions. The sampling probe which was used for both species, consisted of a 1½-ft length of 316 stainless steel tubing extending 6 in. into the duct through the port nipple opposite the SASS sampling ports. Immediately outside the nipple, the tubing was bent 90°, fitted to a monel ball and attached to the inlet of the glass cyclone. Heat tracing from the port exit to the hot box was not necessary due to the high flue gas temperature.

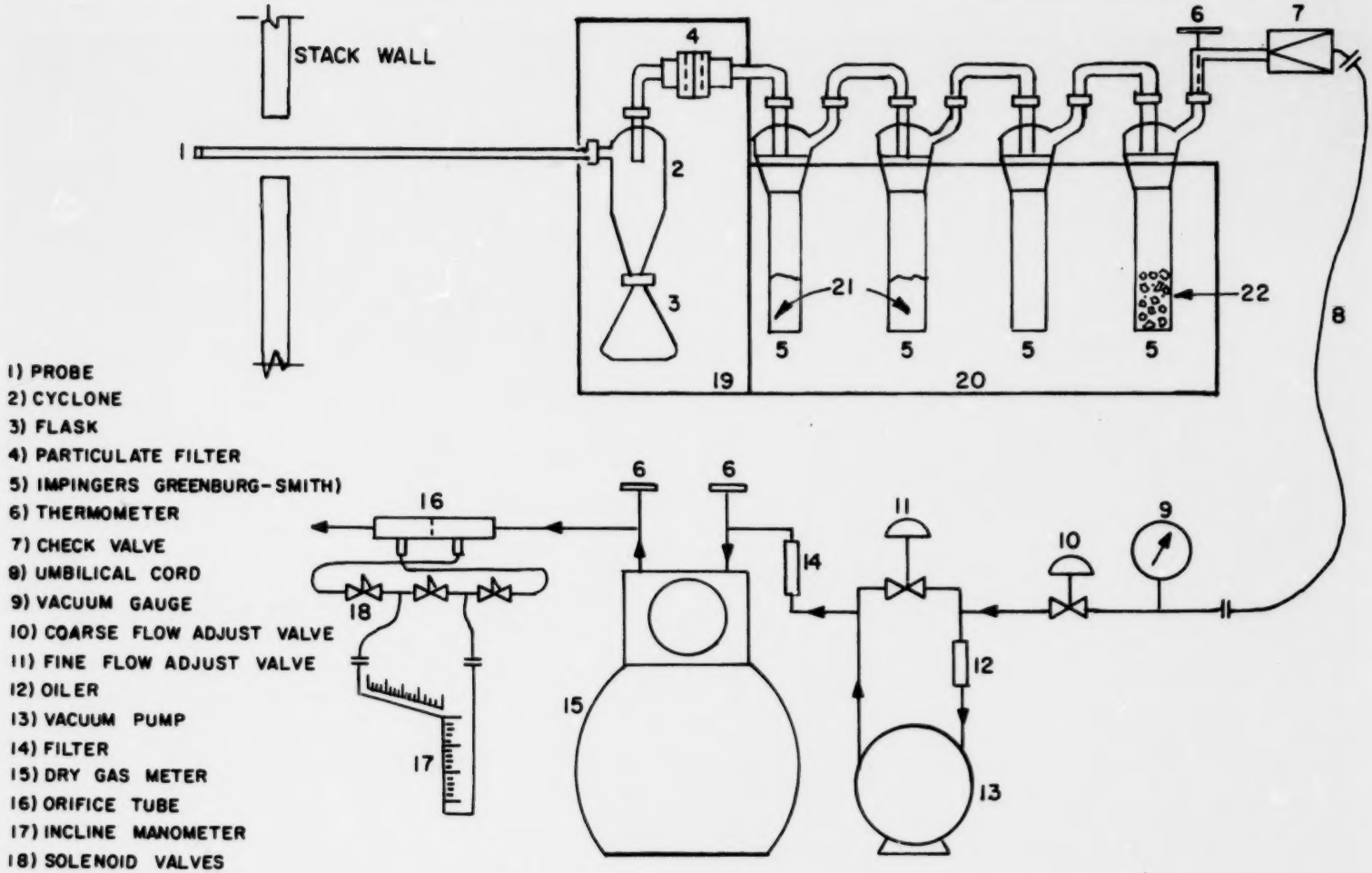

Figure 4. Schematic of reduced nitrogen sampling trains.

A single point sample was taken for each species at approximately 0.6 scfm, maintaining a constant (± 10 percent) sampling rate. Ammonia was sampled through 0.02N H_2SO_4 for 1 hour, and cyanides through 1N NaOH for 2 hours. The cyclone and filter were maintained above 300°F during each ammonia run to prevent the precipitation of ammonium sulfate. During each cyanide run, the cyclone and filter were maintained at 250°F.

Following each run, the impinger solutions were combined into a single sample and the impingers and connectors rinsed with distilled-deionized water. The volume increase in the impingers and weight gain in the silica gel were recorded for moisture determination. HCN was determined onsite; NH_3 impinger samples were returned (at 4°C) to the GCA laboratory for analysis.

One set of four grab samples was collected over a 1-1/2 hour period for determination of NO_x, using EPA Method 7. As noted above, NO_x concentrations in flue gas were also monitored by B&W during the test runs. Strip chart recordings from the Beckman Model 951 continuous NO_x monitor were obtained for each nitrogen run for comparison with GCA data.

Organic Species

A 1-hour integrated bag sample was obtained for onsite GC analysis of organic species in the combustor flue gases. Analyses were run for species in the overall boiling point range of -160 to 100°C.

Other Sampling

Samples for analysis of SO_2, SO_3^-, $SO_4^=$, HF, and HCl in flue gas were obtained using a Goksoyr-Ross controlled condensation system. The sampling train is depicted schematically in Figure 5. Two complete runs were conducted, and sampling was accomplished using the same port as the SASS probe.

Two problems can be associated with the first run: (1) an unacceptable leak was found and measured through the metering system, although no leak was detected through the controlled condensation system. The volume of gas sampled was corrected for the leak through the dry gas meter; and (2) some contamination of the peroxide (first) impinger solution with carbonate (second) impinger solution occurred during leak checking. Analysis of both solutions was unaffected. These problems were not encountered in the second run because a second metering system was obtained to replace the faulty system.

Samples from both runs were recovered following Level 1 procedures, except methanol (distilled-in-glass grade) was substituted for acetone in the probe rinse. Samples were iced for shipment to the GCA laboratory for analysis.

Sampling of Solid Streams

As listed in Table 3, five solid streams were sampled at B&W/Alliance as part of this program. All samples were taken by B&W personnel and provided to GCA field team members.

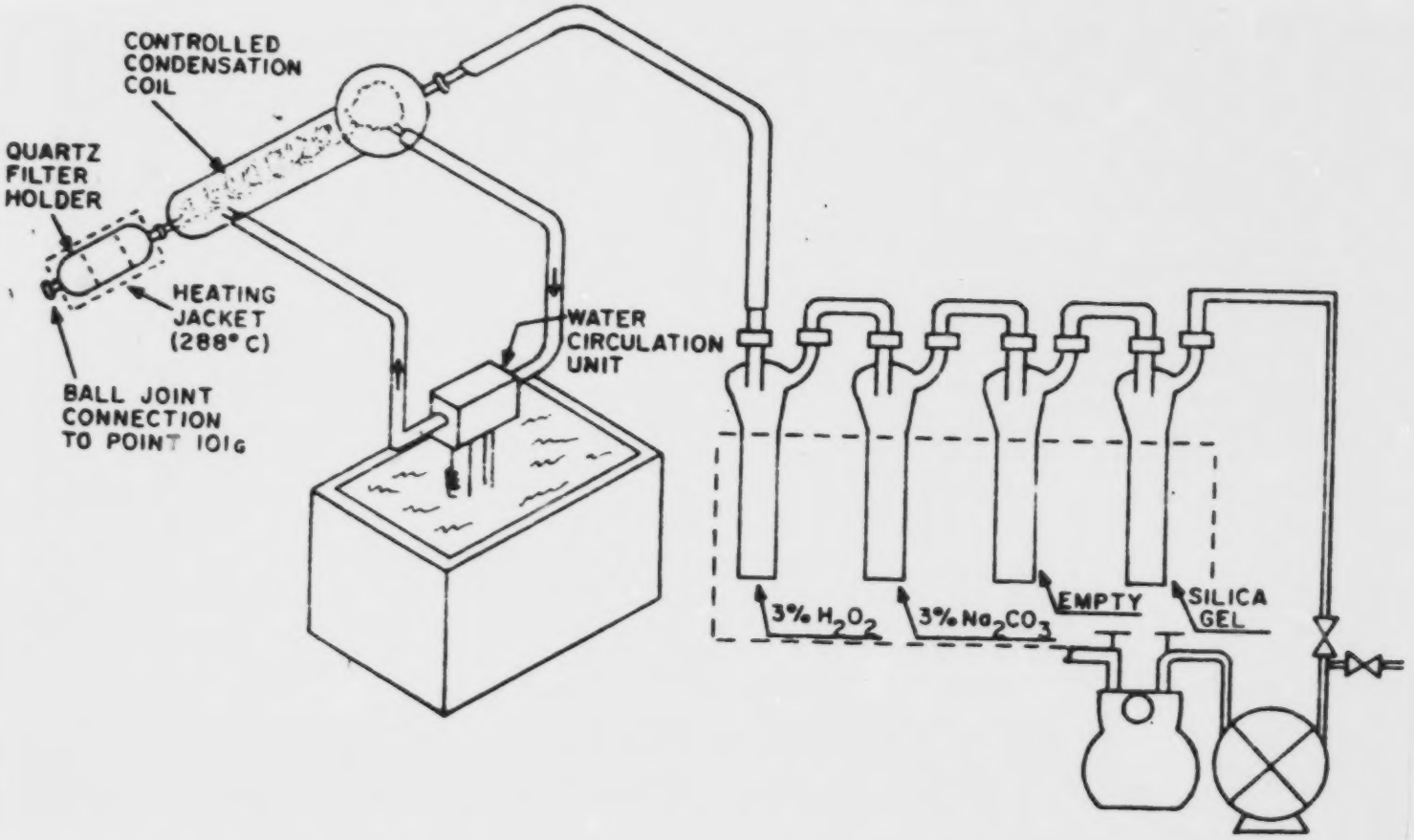

Figure 5. Goksoyr-Ross controlled condensation system.

Diverters in the feed lines enabled sampling of coal and limestone before they were pneumatically injected into the combustor. Full-cut stream samples were obtained every hour during the test runs.

Spent bed solids were obtained from a diverter in the bed withdrawal piping. Solids captured by the cyclones and the baghouse were sampled at the respective outlet sites by B&W personnel.

All solid samples received by GCA field team personnel were split for organic and inorganic analyses. The individual organic and inorganic samples were each composited during the course of the test run to provide a representative sample.

Sample Handling Prior to Analysis

All Level 1 quality control recommendations were followed in handling the samples following the sampling program and prior to chemical or biological testing. Samples from the individual sampling trains were quantitatively transferred into labeled containers for shipment. Table 5 lists these samples and their respective containers.

TABLE 5. SAMPLE CONTAINMENT

Sample	Containment
Particulate filters	Glass petri dishes, stored in desiccator
SASS cyclone catches	Tared Nalgene bottles
SASS probe and impinger wash (methylene chloride/methanol)	Amber glass bottles, caps with Teflon liners
SASS impinger solutions (0.2M $(NH_4)_2S_2O_8$/0.02N $AgNO_3$)	Nalgene bottles
XAD-2 cartridge	Amber glass bottles
Condensate reservoir	Amber glass bottles
Impinger solutions from HCl and HF train	Polyethylene bottles
Impinger solution from HCN train	Polyethylene bottles
Impinger solution from NH_3 train	Glass bottles, caps with Teflon liners
Goksoyr-Ross front wash	Amber glass bottles
Goksoyr-Ross coil rinse	Nalgene bottles
Goksoyr-Ross impingers	Nalgene bottles
Method 7 NO_x samples	Nalgene bottles

All SASS impingers and impingers from special sampling trains (e.g., NH_3, Goksoyr-Ross) were refrigerated (4°C) both in the field and in the laboratory. These samples were also maintained at 4°C during transport back to GCA.

Immediately following sampling, spent bed solids, cyclone catch and bag-house catch were transported to Battelle Columbus Laboratories for generation of leachate and subsequent bioassay.

SECTION 4

ANALYTICAL TECHNIQUES

This section presents an overview of the instrumental and wet chemical analytical techniques used to characterize the components of the streams sampled at the B&W/Alliance AFBC. Also discussed are the assays used to assess the biological activity of these samples. The analytical and bioassay methodologies employed were generally those outlined in the Level 1 Procedures Manual.[1] Any variation from these specified procedures is discussed.

ONSITE ANALYSES

As outlined in Section 3, onsite sampling and analysis was limited to quantification of flue gas stream components by gas chromatography. The single exception was analysis for HCN by the colormetric pyridine-pyrazolone method using a Hach kit on a butyl alcohol extract of the 1N NaOH impinger of the reduced nitrogen sampling train (see Figure 4).

Fixed Gases

Fixed gases CO_2, O_2, and N_2 were analyzed using an analytical instrument development (AID) gas chromatograph with a thermal conductivity detector (GC/TCD).

Column: Molecular 13X on 40/60 mesh; 4-ft x 1/8-in. stainless steel
Chromosorb 102: 6-ft x 1/8-in. stainless steel

The detection limit was 25 ppm. The concentration of CO was below the detection limit of the GC/TCD so this species was quantified using Kitagawa detector tubes with a a detection of 1 ppm.

Sulfur Species

SO_2, H_2S, COS, and methylmercaptan (MMC) were analyzed with a Perkin-Elmer model 3920 gas chromatograph using a flame photometric detector (GC/FPD) equipped with a 394 nm filter.

Column: 12 percent polyphenol ether, 0.5 percent H_3PO_4 on 40/60 Chromosorb T; 36-ft x 1/8-in. clear Teflon

Detection limit was 10 ppm

Organic Analysis

Grab samples were analyzed for organic species within the boiling point ranges -160 to 100°C. GC1-GC4 (bp -160 to 30°C) were analyzed with a Perkin-Elmer model 3920 gas chromatograph using a flame ionization detector (GC/FID).

Column: Poropak Q on 80/100 mesh; 6 ft x 1/8-in. stainless steel.

GC5-GC7 (pb 30-100°C) were analyzed with an analytical instrument development model 511 gas chromatograph, also with an FID.

Column: 20 percent OV-101 on 100/120 mesh Chromosorb-W-HP; 6-ft x 1/8-in. glass

Detection range for both was 3-8 $\mu g/m^3$.

Data analysis for GC5-GC7 using the AID GC/FID revealed that the flame ionization dector had caused a slow continual climb in oven temperature from 30 to 65°C during the test program. This rise in oven temperature prevented maintenance of gas chromatography conditions specified in the Level 1 manual. Under the test conditions, no GC5-GC7 species were detected. The gas chromatogram from the P-E 3920 GC/FID used to analyzed for GC-GC4 with the Poropale Q column was used to substantiate the data for GC5-GC7 after completion of the GC1-GC4 temperature program. PE 3920 data for all samples tested corroborated the absence of any GC5-GC7 species within the specified detection range.

Inorganic Analytical Techniques

Quantification of inorganic chemical constituents of B&W/Alliance stream samples was accomplished using those techniques specified in the Level 1 Procedures Manual.[1] Spark source mass spectrometry (SSMS) and atomic absorption (AA) techniques were combined to conduct a survey of trace element concentrations in appropriate samples. Figure 6 presents an overview of Level 1 inorganic methodology as it applied to B&W/Appliance samples. Table 6 provides a summary of these inorganic analyses which were performed on B&W/Alliance samples. As noted in Table 5, B&W/Alliance bulk solid streams having the potential to be disposed of in a landfill or other area where leaching could occur (this included spent bed material and cyclone catch) were subjected to inorganic analysis of both the solid material and laboratory-generated distilled water leachates. Testing of leachates included quantification of certain anionic species by ion chromatography (IC) in addition to SSMS and AA.

SAMPLE PREPARATION PROCEDURES

Some samples required special preparation before analysis for inorganic chemical constituents. XAD resin samples were prepared for analysis by combustion over 1:1 HNO_3 in a Parr Oxygen Bomb. Approximately 1 gram of resin sample was weighed into a vycor dish and colloidion was added to ensure complete combustion. The sample was placed in the bomb, pressurized to 30 atmospheres

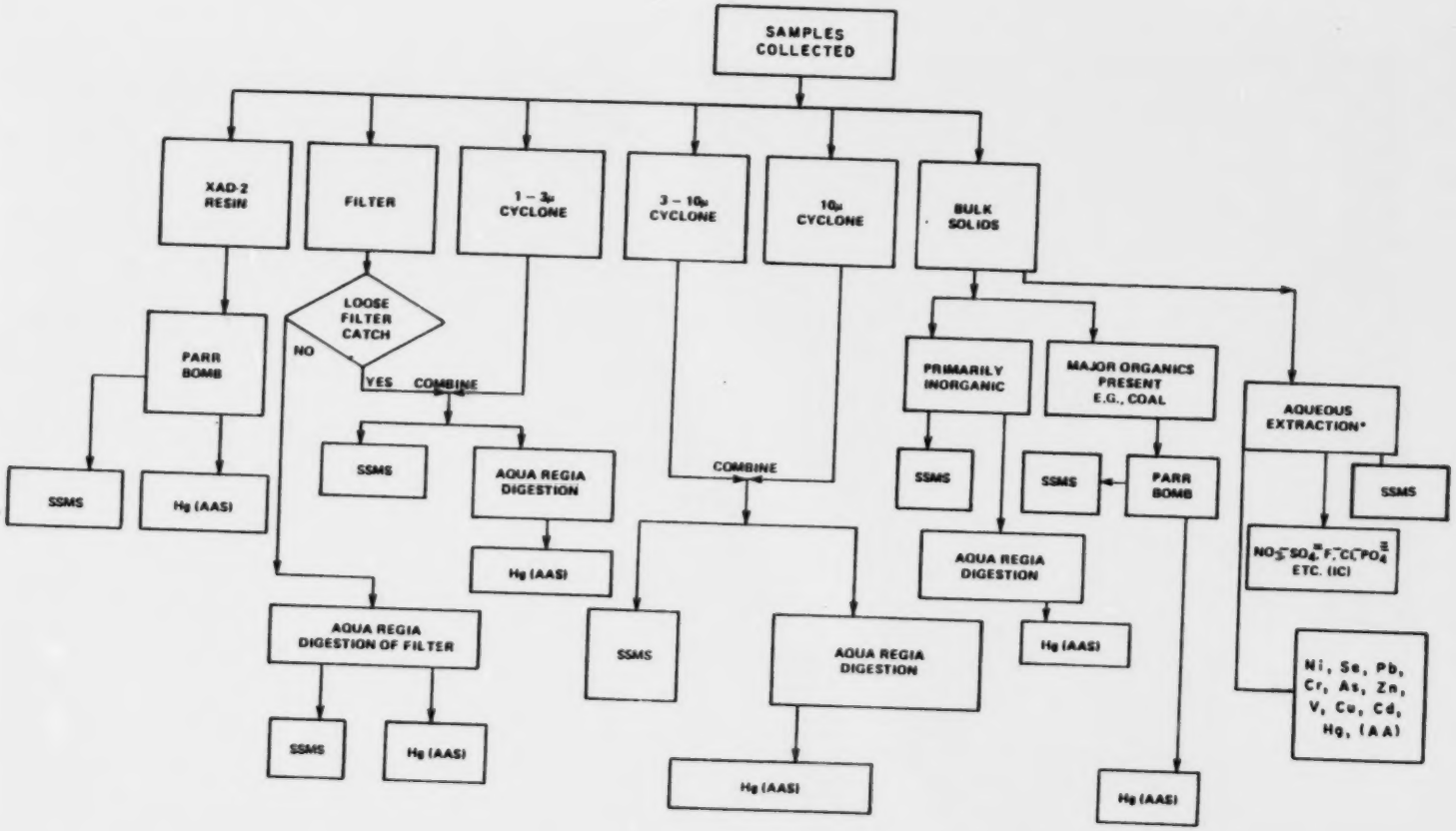

Figure 6. Level 1 inorganic laboratory analysis plan.

TABLE 6. SUMMARY OF INORGANIC ANALYSES PERFORMED ON B&W/ALLIANCE STREAM SAMPLES

Sample description	Analytical technique			
	SSMS	AA[a]	IC	Aqueous extraction[b]
Flue gas (SASS components)				
SASS coarse particles (3-10μm) (BW1-1-01-CC)	✓	✓		
SASS fine particles (1-3μm) (BW1-1-01-FC)	✓	✓		
SASS particulate filter (<1μm) (BW1-1-01-PF)	✓	✓		
SASS XAD-2 resin (BW1-1-01-XM)	✓	✓		
SASS impinger train (BW1-1-01)		✓	✓	
Bulk solids				
Cyclone catch (BW1-1-03-CP)	✓	✓	(✓)[c]	✓
Spent bed material (BW1-1-04-CB)	✓	✓	(✓)	✓
Coal feed (BW1-1-05-CF)	✓	✓		
Sorbent feed (BW1-1-06-SF)				

[a] Level 1 methodology specifies Hg to be quantified by AA; B&W/Alliance samples (solids) were analyzed by AA for Hg, As, and Sb.

[b] Laboratory-generated distilled water leachate.

[c] (✓) indicates ion chromatography was performed on leachates only. SSMS and AA were run to quantify trace element in leachates (see Figure 6. and text).

with oxygen, and ignited. For SSMS analysis, the bomb rinsings were combined with the remaining residue and mixed with graphite prior to electrode formation. For AA analysis, the contents of the bomb were washed into a beaker, filtered and diluted to 50 ml prior to analysis.

SASS particulates required preparation prior to AA analysis. These samples were extracted with 4:1 nitric:hydrochloric acid. Approximately 1 gram of sample was placed in a distillation flask with 60 ml of the boiling flask were filtered, washed into a 100 ml volumetric flask and diluted to volume. SASS filter samples were prepared in a similar manner for both AA and SSMS analysis. An alternate extraction procedure, ASTM D 3683-78, was used in the preparation of bulk solid waste streams and coal. This procedure involves dissolution of the sample using hydrofluoric acid and aqua regia; in the case of coal or other materials which are primarily organic, the sample must undergo low temperature ashing as a preliminary step. SASS impinger samples required no additional preparation for either AA or SSMS analysis.

ANALYTICAL METHODS

Spark Source Mass Spectrometry (SSMS)

SSMS was the primary method of inorganic analysis for the majority of B&W/Alliance Level 1 samples. The instrument used, a JEOL Analytical Instruments, Inc., Model JMS-01BM-2 Mass Spectrograph, is a high resolution, double focusing mass spectrometer with Mattauch-Heizog ion optics and ion sensitive photoplate detection. The instrument is designed to carry out high sensitivity trace element analysis of metals, powders or semiconductor type materials using an RF spark ion source. An aliquot of each sample to be analyzed must be incorporated into two electrodes which are mounted in the ion source of the mass spectrometer. The electrodes are decomposed by the application of a radio frequency (~ 30 KV); the beam is then focused to produce a mass spectrum, which is recorded by an ion sensitive photoplate.

SSMS can be used to detect elemental concentrations at levels as low as 10^{-9}g (one nanogram). Although the sensitivity varies somewhat, depending upon the element of interest and the sample type, nearly all elements in the periodic table (exceptions are H, C, N, O and the inert gases) can be detected. When photoplate detection is used, all elements with mass in the range of 6 to 240 can be detected simultaneously. Element concentration is derived from the intensities (optical density) of the mass spectral lines; methods for determining concentration data from photoplate spectral line densities vary somewhat in terms of their complexity and the corresponding precision and accuracy of the results. The photoplate interpretation procedures followed for this program and for Level 1 survey work in general are designed to yield concentration data accurate to within a factor of 2 for 70 elements.

Interferences result from the formation of multiple charged ions, ion clusters and molecular ions such as oxides, hydrides, hydroxides and carbides. These interferences, coupled with the fact that the discharge conditions in the ion source are not easily reproduced, tend to limit the accuracy of the technique. SSMS is, however, a useful survey tool and is capable of providing semi-quantitative results which are accurate within a factor of 2 or 3.

Table 7 shows SSMS operating parameters for the B&W/Alliance test program. Typical detection limits for liquid and solid samples are shown in Table 8.

TABLE 7. SSMS OPERATING PARAMETERS

Pulse Repetition Rate	100 Hz
Pulse Length	40 μsec
Magnet Current	4.00 A
Accelerating Voltage	28.3 KV
Analyzer Pressure	$4x10^{-9}$ torr
Source Pressure	$5x10^{-7}$ torr

Atomic Absorption Spectrophotometry (AA)

AA was used to quantify mercury, arsenic, and antimony in the B&W/Alliance flue gas stream and in bulk solids. This technique was also used to determine concentrations of 10 trace elements in laboratory-generated distilled water leachates of B&W/Alliance solid samples.

AA techniques involve the generation of a population of free, uncombined atoms in the ground state using either flame or flameless methods and subsequent exposure of this population to light at the characteristic absorption wavelength. The sample absorbance is then compared to standard absorbances. The concentrations which can be determined by this method range from parts per billion to several hundred parts per million in solution. All atomic absorption analysis was done using a Perkin-Elmer Model 460 spectrophotometer equipped with deuterium arc background correction and Perkin Elmer HGA-2100 Graphite Furnace. The operating parameters for mercury, arsenic, and antimony determinations are summarized in Table 9.

Arsenic and antimony analyses were done using graphite AA. Sample volumes of 20 or 50 μl were injected into the furnace and the resulting absorbance compared to standard absorbances. Solution detection limits for these elements are on the order of 5 μg/l (equivalent to emissions of 0.25 $\mu g/m^3$).

Mercury was quantified using the cold vapor method. In this procedure, all mercury was initially oxidized to the Hg^{+2} state by the addition of nitric and sulfuric acids to the sample aliquot; the sample was then diluted to a known volume and placed in the reaction vessel. The mercury was reduced to the elemental state by the addition of stannous chloride and aerated from solution in a closed system. The resulting absorbance value was then compared to standard absorbances. The detection limit for this procedure is 1 μg/l (equivalent to 0.05, 0.25, and 0.0033 $\mu g/m^3$ emissions in impingers, XAD, and particulate samples, respectively).

Leachate Generation and Analysis

Bulk solid streams from the B&W/Alliance AFBC (cyclone ash and spent bed material) were subjected to leachate generation and subsequent analysis. These

TABLE 8. AVERAGE SSMS DETECTION LIMITS FOR 50 mg B&W/ALLIANCE PARTICULATE SAMPLE[a]

Element	Value (ppm)	Element	Value (ppm)
U	<0.68	RU	<0.50
TH	<0.96	MO	<0.31
BI	<0.41	NB	<0.23
PB	<0.93	ZR	<0.57
TL	<0.50	Y	<0.23
HG	<1.0	SR	<0.13
AU	<0.60	RB	<0.041
PT	<1.8	BR	<0.69
IR	<0.93	SE	<0.32
OS	<1.0	AS	<0.14
RE	<0.64	GE	<0.21
W	<0.43	GA	<0.088
TA	<0.64	ZN	<0.18
HF	<2.1	CU	<0.092
LU	<0.52	NI	<0.21
YB	<0.38	CO	<0.091
TM	<0.22	FE	<0.091
ER	<0.65	MN	<0.046
HO	<0.11	CR	<0.030
DY	<0.37	V	<0.067
TB	<0.072	TI	<0.082
GD	<0.37	SC	<0.073
EU	<0.26	CA	<0.041
SM	<0.78	K	<0.008
ND	<0.54	CL	<0.14
PR	<0.14	S	<0.12
CE	<0.19	P	<0.051
LA	<0.39	SI	<0.020
BA	<0.29	AL	<0.009
CS	<0.034	MG	<0.012
I	<0.12	NA	<0.004
TE	<0.45	F	<0.13
SB	<0.33	B	<0.063
SN	<0.39	BE	<0.008
CD	<0.11	LI	<0.002
AG	<0.17		
PD	<0.62		
RH	<0.16		

[a]Detection limit for all elements (except PT) in a 50 ml leachate sample was <0.001 ppm. PT was <0.002 ppm.

TABLE 9. AA OPERATING PARAMETERS (PERKIN-ELMER MODEL 460 AA SPECTROPHOTOMETER WITH HGA-2100 GRAPHITE FURNACE)

	Hg	As	Sb
Source	Hollow cathode lamp/6mA	Electrodeless discharge lamp/6mA	Electrodeless discharge lamp/6mA
Wavelength	253.6 nm	193.6 nm	217.3 nm
Slit	0.7 nm	0.7 nm	0.2 nm
Drying time/temperature	NA	30 sec/110°C	30 sec/120°C
Charring time/temperature	NA	30 sec/500°C	30 sec/700°C
Atomizing time/temperature	NA	10 sec/2700°C	10 sec/2700°C

NA = Not applicable.

procedures were designed to provide an estimate of the relative environmental hazard (when evaluated with bioassay data and relative emission goals) resulting from leaching of bulk solid wastes relegated to disposal areas.

Chemical characterization of the leachate from each of the bulk solid waste materials was accomplished through the combined use of Ion Chromatography (IC), Atomic Absorption (AA) and Spark Source Mass Spectrometry (SSMS).

Leachate Generation Procedures

Fifty grams of solid material was dried at 104° ± 2°C for 18 ± 2 hours to determine the percentage of moisture in the sample. If necessary, the drying was repeated until a constant weight was achieved.

A representative sample of waste (350.0 grams) was weighed to the nearest tenth of a gram in a 2-liter LPE bottle.

Distilled, deionized water was boiled and cooled to maintain an approximate starting pH of 6.0 (ASTM Type IV water). The quantity of water added (1400 ml) was equal to four times the weight in grams of the sample.

The container was closed and agitated continuously for 48 ± 0.5 hours at 20 ± 2°C. The samples were shaken at 60 1-inch strokes/minute.

After 48 hours, the aqueous phase was separated by filtering through a 0.45 µm Millipore membrane filter.

An 8-ounce LPE bottle was completely filled with the filtrate (~275 ml) and refrigerated for future IC analysis. Another portion of the extract was acidified to pH 2 with 1:1 Ultrex nitric acid for AA and SSMS analysis.

Ion Chromatography (IC)

Quantification of anions in generated leachates was accomplished using a Dionex Model 14 Ion Chromatograph. The column system employed (1) a precolumn (3 x 150 mm) to remove particulates, strongly retained anions, and organic species; (2) a separator column (3 x 500 mm) in the HCO_3^- form to chromatographically separate the anions; and (3) a suppressor column (6 x 250 mm) in the H^+ form to remove the background conductivity of the eluent. A solution of 0.003 M $NaHCO_3$/0.0024 M Na_2CO_3 was used for the eluent at a 30 percent flow rate (about 140 ml/hr). The injection loop had a volume of 100 µl, and the sample was introduced from a 5 ml disposable syringe fitted with a 0.22 µm Millipore filter to remove particulate matter. A 1N H_2SO_4 solution regenerated the suppressor column for 15 minutes after an 8-hour period.

Detection limits for the IC analyses are given in Table 10.

TABLE 10. DETECTION LIMITS FOR ION CHROMATOGRAPHY

Anion	Detection limit (µg/l)
F^-	50
Cl^-	100
Br^-	100
NO_2^-	80
NO_3^-	100
$SO_4=$	100
$PO_4\equiv$	100

AA Analysis of Leachates

Atomic absorption analyses were performed on leachate samples using a Perkin-Elmer Model 460 Spectrophotometer, equipped with deuterium arc background correction. The metals determined in the leachates included nickel, arsenic, zinc, vanadium, copper, cadmium, chromium, mercury, lead, and selenium. All metals, except Hg and Zn, were analyzed by the flameless AA technique with a Perkin-Elmer HGA-2100 Graphite Furnace. The operating parameters and detection limits for each element are listed in Table 11. The drying, charring, and atomization cycles were optimized for each element. Data for the standard solutions and leachate samples were recorded in the peak height mode of the instrument. Aliquot volumes of 50 or 25 µl were pipetted into the furnace with an Eppendorf pipet. For the analyses of As and Se, an equal volume of a 1000 ppm Ni solution (as $Ni(NO_3)_2$) was added to the furnace.

Calibration curves were used to quantify the data and determine the linear working ranges for the metals. The standard solutions were prepared in deionized water which had been acidified to pH less than 2 with Baker Ultrex nitric acid. For quality control purposes, EPA trace metal samples were analyzed. Some leachates were also analyzed by the method of standard additions to ensure that no matrix interferences existed. Mercury was quantified using the cold vapor method previously described. Since small quantities (10 ppb) of zinc can be determined using flame AA methods, zinc was analyzed using an air-acetylene flame. The results at 213.4 nm were recorded in the absorption mode.

Organic Laboratory Techniques

The laboratory measurements and analytical techniques used to quantify organic constituents in B&W/Alliance stream samples followed a multisegmented approach. Preliminary organic analyses were those specified in the Level 1 Procedures Manual. The Level 1 test protocol attempts to identify the major organic compound classes within each sample stream tested. Qualitative and quantitative data are generated from the combined use of gravimetry (GRAV), determination of total chromatographable organics (TCO), infrared spectroscopy (IR) and, where Level 1 decision criteria dictate, low resolution mass spectrometry (LRMS) and liquid chromatographic separation (LC). Level 1 organic

TABLE 11. OPERATING PARAMETERS AND DETECTION LIMITS FOR TRACE METALS IN LEACHATE ANALYZED BY AA

Metal	As	Cd	Cr	Cu	Pb	Ni	Se	V
Source	EDL	EDL	HCL	HCL	HCL	HCL	EDL	HCL
Wavelength (nm)	193.3	228.2	357.4	324.5	283.0	232.1	195.7	317.9
Slit (nm)	0.7	0.7	0.7	0.2	0.7	0.2	0.2	0.7
Background correction	No	No	No	No	No	No	No	No
Purge gas	Ar	Ar	Ar	Ar	Ar	Ar	Ar	Ar
Gas interrupt	Yes	No	No	No	No	No	Yes	No
Drying temperature/time	120°C/40 sec	120°C/30 sec	120°C/30 sec	120°C/30 sec	120°C/50 sec	120°C/50 sec	120°C/30 sec	120°C/30 sec
Charring temperature/time	500°C/30 sec	350°C/30 sec	1100°C/30 sec	900°C/30 sec	500°C/30 sec	1000°C/30 sec	700°C/30 sec	700°C/30 sec
Atomization temperature/time	2700°C/10 sec	2100°C/10 sec	2700°C/10 sec	2500°C/10 sec	2300°C/10 sec	2700°C/10 sec	2700°C/10 sec	2700°C/10 sec
Detection limit[6] (ppb)	1.0	0.1	1.0	0.5	1.0	25	5.0	10

[a]HCL = follow cathode lamp.

EDL = electrodeless discharge lamp.

[b]Detection limit for Hg was 1.0 ppb by the cold vapor method.

Detection limit for Zn was 10 ppb flame AA.

analysis methodology is outlined in Figure 7. Table 12 summarizes the Level 1 organic analyses performed on indicated B&W/Alliance samples.

Organic analysis of certain B&W/Alliance stream samples was extended to include a technique beyond the recommended Level 1 protocol. High performance liquid chromatography (HPLC) with fluorescence detection was used on indicated samples to characterize polynuclear aromatic hydrocarbon (PNA) species.

Sample Preparation Procedures--

Gaseous stream samples--Sample preparation for organic analysis of these samples consisted of extraction of the adsorbent resin (XAD-2) modules used as part of the SASS sampling train.

Each of the sorbent/module rinses was aliquotted and combined prior to extraction. The extraction sequence took place in a soxhlet extractor using methylene chloride for 24 hours. The extracts were concentrated to 10.0 ml via rotary evaporation under reduced pressure at 25°C.

Solid samples--Solid samples designated for organic analysis are listed in Table 12. This included all SASS cyclones and particulate filter catches, probe rinses and bulk solid samples. Preliminary analysis of bulk solids consisted of sample homogenization using riffling techniques.

Typically, 100 grams of each of the bulk solid samples was extracted for 24 hours in a soxhlet apparatus with methylene chloride. Each extract was than filtered, dried and concentrated to a final volume of 10.0 ml, using a rotary evaporator under reduced pressure at 35°C.

Analytical Methods--

Brief descriptions of the organic analytical methods used in conducting Level 1 organic analysis of B&W/Alliance stream samples are presented below. Included is a discussion of the HPLC/Fluorescence procedures used to provide data on concentrations of PNA species in indicated samples. Where appropriate, samples of typical data output from these methods are included.

Gravimetry--

The purpose of the gravimetric analysis is to quantify organic constituents with boiling points greater than 300°C. Typical analyses consist of pipetting a 1.0 ml aliquot of each 10.0 ml sample extract into a precleaned and tared aluminum weighing pan. After a period of sample dessication, to remove residual solvent, each sample is weighed to a constant weight of ±0.1 mg.

While the analysis is useful in the assessment of total nonvolatile organics residues, errant values may result due to positive interferences from inorganic constituents.

Total chromatographable organics (TCO)--Chemical analysis of moderately volatile organic materials (pb 100 to 300°C) was accomplished by gas chromatography coupled with flame ionization detection. Instrument operating conditions are summarized in Table 13.

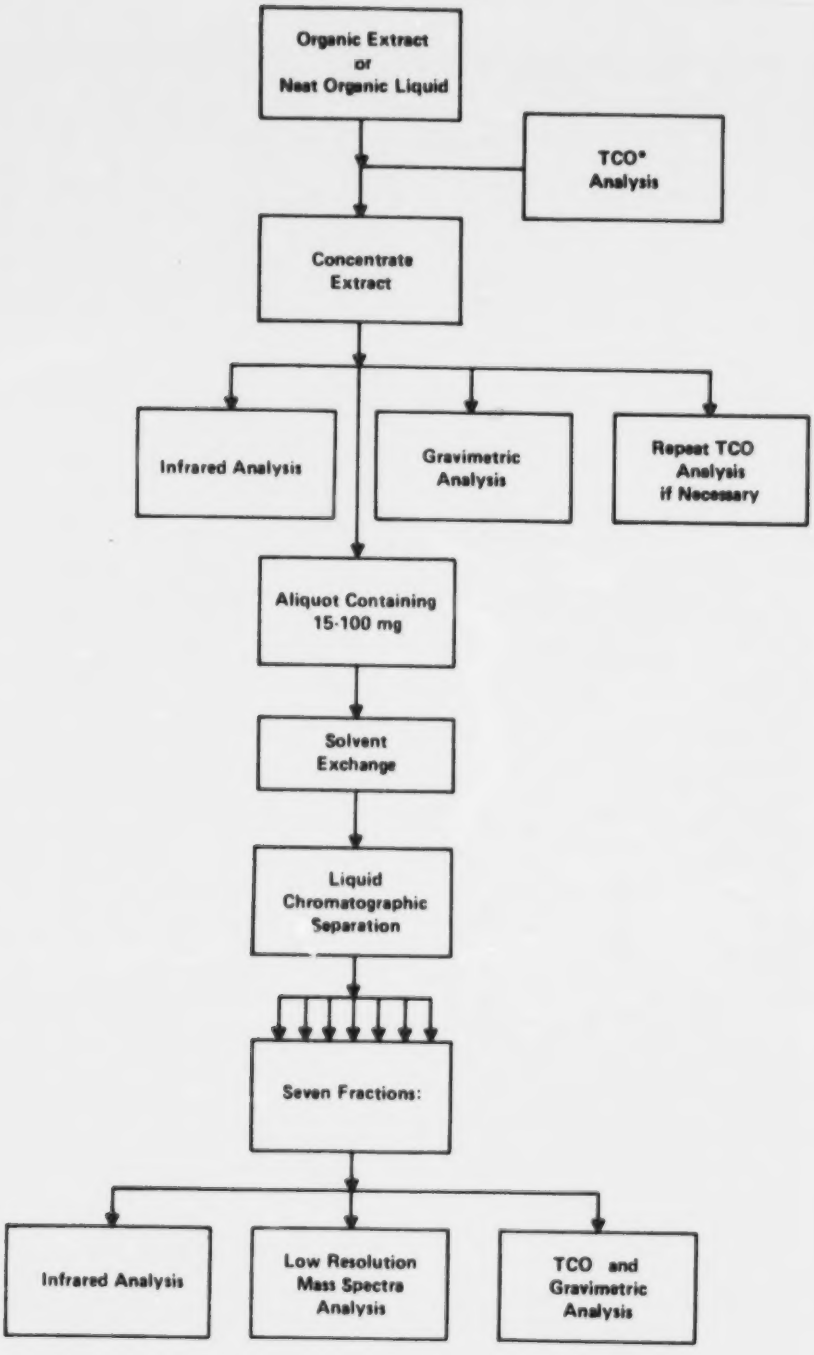

Figure 7. Organic analysis methodology.

TABLE 12. SUMMARY OF ORGANIC ANALYSES PERFORMED ON B&W/ALLIANCE STREAM SAMPLES

Sample description	Analytical techniques						
	Onsite GC	CH_2Cl_2-extraction	TCO	GRAV	IR	LC	HPLC/Flu[a]
Combustor flue gas - grab sample	✓	-	-	-	-	-	-
SASS train components							
Combined coarse (3-10 μm) particulate catch	-	✓	-	✓	✓	-	✓
Combined fine (< 3 μm) particulate catch	-	✓	-	✓	✓	-	✓
Probe rinse	-	NA	NA	NA	NA	NA	NA
Sorbent module condensate	-	✓	✓	✓	✓	-	-
XAD-2 resin and sorbent module rinse	-	✓	✓	✓	✓	✓[b]	✓
Bulk solids							
Cyclone catch	-	✓	✓	✓	✓	-	✓
Spent bed material	-	✓	✓	✓	✓	-	-
Coal feed	-	✓	✓	✓	✓	✓[b]	-
Sorbent feed	-	-	-	-	✓	-	-

- = Not run

NA = Not analyzed because Level 1 criteria were not exceeded (GRAV was not > 10 percent of total particulate catch).

[a]All samples screened by HPLC/Flu were Day 1 samples (i.e., BW1-1-01-CC, BW1-1-01-FC, BW1-1-01-XM, BW1-1-03-CP). Appropriate XAD-2 and solvent blanks were also run.

[b]The two samples receiving LC fractionation did not exceed Level 1 criteria for LRMS of fractions; TCO, GRAV, and IR were performed on these LC fractions. Day 2 samples of XAD-2 extract were LC fractionated (BW1-2-01-XM); both Day 1 and Day 2 samples (BW1-1-05-CF and BW1-2-05-CF) of coal feed were fractionated.

TABLE 13. TOTAL CHROMATOGRAPHABLE ORGANICS (TCO) OPERATING PARAMETERS

Instrument:	Tracor 560 gas chromatograph with dual FID.
Recorder/Integrator:	Hewlett-Packard 3380S
Chart Speed:	1 cm/min
Column:	10% SP-2100 on Supelcoport 100/120 6 ft x 2 mm id glass column
Carrier Gas:	20 ml/min prepurified N_2.
Oven Temperature:	50°C for 5 min, programmed 50 to 250°C at 10°/min, hold at 250°C for 5 min.
Injector Temperature:	275°C
Detector Temperature:	300°C
Injection Volume:	2.0 µl

This technique is designed to provide both qualitative and quantitative information on appropriate sample extracts. The qualitative analysis divides each sample into discrete boiling point ranges, which are defined by a mixture of n-alkanes (C_7 - C_{17}). This is accomplished through the use of retention time data recorded for standard mixtures of these materials.

Figure 8 depicts a typical chromatogram of an n-alkane mixture (C_7 - C_{17}) including suggested boiling point boundaries for each alkane region.

Liquid chromatographic (LC) separations--This procedure was designed to separate samples into reasonably distinct classes of compounds and was applied to all organic samples which contained a minimum of 500 µg/m^3 of combined volatile (TCO) and nonvolatile (gravimetric) organics. A sample weighing from 9 to 100 mg was placed on a silica gel liquid chromatographic column, and a series of eluents of sequentially increasing polarity was employed to separate the sample into fractions for further analyses. Table 14 lists compound classes typically isolated in each fraction. Also shown are solvent compositions of each eluent.

Because of the limited organic loadings for the majority of the B&W/Alliance sample streams, LC fractionation was conducted in only two instances. The CH_2Cl_2-extract of the SASS XAD resin from the B&W/Alliance flue gas stream (BW1-1-01-XM and BW1-2-01-XM) and the coal feed (BW1-1-05-CF and BW1-2-05-CF) were the only samples receiving LC fractionation and subsequent further analyses (IR only was run on LC fractions; no sample exceeded Level 1 decision criteria to require LRMS).

Infrared Analysis

IR analysis was used to determine the functional groups in an organic sample or LC fraction of a partitioned sample. The interpreted spectra

Boiling Point Region Assignment C_8-C_{16} (C^o)			
C_8	100-140	C_{13}	220-240
C_9	140-160	C_{14}	240-260
C_{10}	160-180	C_{15}	260-280
C_{11}	180-200	C_{16}	280-300
C_{12}	200-220		

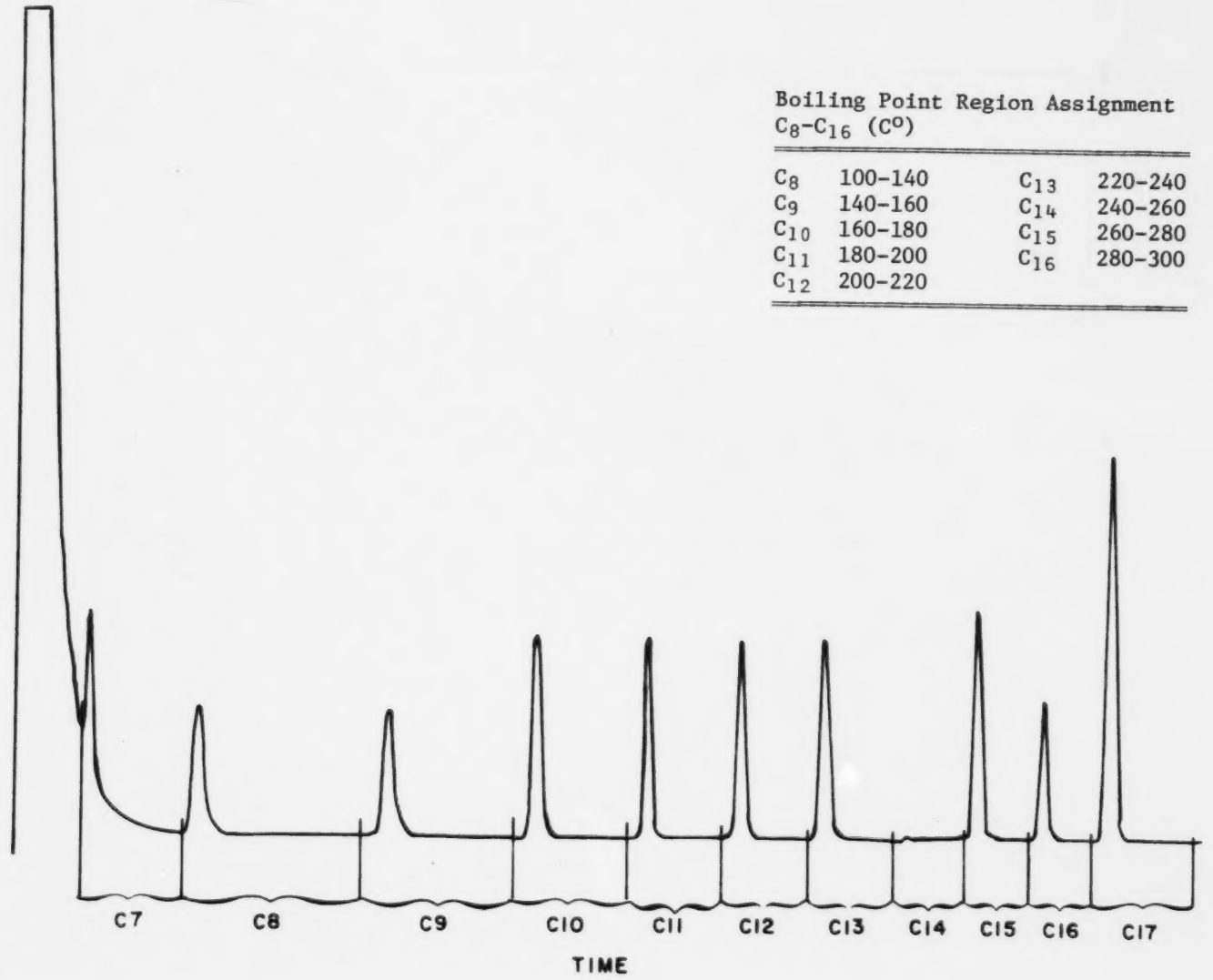

Figure 8. Chromatogram (TCO) of n-alkane calibration mixture for boiling point distribution analysis.

TABLE 14. SUMMARY OF SUGGESTED ORGANIC CLASS DISTRIBUTION FOR LC FRACTIONATION SCHEME

Fraction #1 Pentane	Fraction #2 20% Methylene Chloride in Pentane	Fraction #3 50% Methylene Chloride in Pentane	Fraction #4 Methylene Chloride	Fraction #5 5% Methanol in Methylene Chloride	Fraction #6 20% Methanol in Methylene Chloride	Fraction #7 50% Methanol in Methylene Chloride
1. Aliphatic hydrocarbons	1. Halogenated aliphatics	1. Aromatic hydrocarbons	1. Nitro aromatic hydrocarbons	1. Nitro aromatic hydrocarbons	1. Alcohols (Primary, secondary, tertiary)	1. Sulfonic acids, sulfoxides
(Alkanes)	(saturated)	(benzenes)	2. Ethers (Halogenated ethers)	2. Phosphates	(Glycols)	2. Carboxylic acids
(Alkanes)	(unsaturated)	2. Halogenated aromatic hydrocarbons	3. Epoxides		2. Phenols (Alkyl, etc.) (Halogenated phenols) (Nitrophenols)	3. Phosphates
(Alkanes)	2. Aromatic hydrocarbons	3. Fused alternate, non-alternate hydrocarbons MW<216 (methyl pyrene) MW>216	4. Aldehydes		3. Esters	
2. Halogenated aliphatics	(benzenes)	4. Heterocyclic oxygen compounds	5. Heterocyclic oxygen compounds		(Phthalates)	
(saturated)	3. Halogenated aromatic hydrocarbons	5. Silicones	6. Nitriles		4. Ketones	
(unsaturated)	4. Fused alternate, non-alternate hydrocarbons MW<216 (methyl pyrene) MW>216		(Aliphatic) (Aromatic)		5. Amines (Primary, secondary, tertiary)	
	5. Silicones		7. Heterocyclic nitrogen compounds		(Hydrazines, azo compounds)	
			(Indoles, carbazoles)		(Nitrosoamines)	
			8. Heterocyclic sulfur compounds		6. Heterocyclic nitrogen compounds	
			(Benzo thiophenes)		(Quinolines, acridines)	
			9. Silicones		7. Alkyl sulfur compounds	
					(Mercaptans) (Sulfides, disulfides)	
					8. Amides	
					9. Carboxylic acids	
					10. Phosphates	

provide information on functionality (e.g., carbonyl, aromatic hydrocarbon, alcohol, amine, aliphatic hydrocarbon, halogenated organic, etc.). Compound identification is possible only when that compound is known to be present as a dominant constituent in the sample.

During the course of this analytical program, IR scans were conducted using either KBr plates or NaCℓ liquid cells. For samples run on KBr plates, sample gravimetric residues were redissolved in a volume of methylene chloride and transferred to the plate in a final volume between 0.1 and 0.2 ml. For samples exhibiting high concentrations of semi-volatile organics (TCO), neat sample extracts were used. Volumes applied varied between 0.1 and 2.0 ml, depending on the predetermined organic loading. Due to solvent interferences, a number of the extracts underwent solvent exchange into carbon disulfide prior to IR analysis using liquid cells. A solution of the sample was prepared in a volume of CS_2 ranging from 0.02 to 0.04 ml. The solution was transferred to the liquid cell and stoppered. All of the above sample types were subsequently scanned from 4000 cm^{-1} to 250 cm^{-1}. For a listing of instrument operating parameters, refer to Table 15.

Interpretation of IR spectra was made in terms of functional groups present. Sample quantities required for analysis were in the (mg) range with a lower limit of approximately 0.5 mg. A single species must be present on a 5-10 percent (w/w) basis to warrant sufficient interpretation of stronger functional groups. For a listing of the more common functionalities with suggested peak intensities and typical detection limits (in $\mu g/m^3$), see Table 16. Figure 9 depicts a typical IR spectrum as recorded for combustor flue gas with the appropriate functional group assignments noted.

HPLC/Fluorescence--Selected B&W/Alliance sample extracts were screened for polynuclear aromatic hydrocarbon (PNA) species using high-performance liquid chromatography with fluorescence detection (HPLC/Flu). These analyses, which are beyond the scope of Level 1 organic analysis, were initiated because of the biological significance of low levels of certain PNAs. In our laboratory, HPLC/Flu is a screening technique used to isolate potentially biologically active species in sample extracts based on the sample fluorescence characteristics. Table 17 lists PNA species screened for using this technique including typical detection limits.

TABLE 15. INFRARED SPECTROSCOPY OPERATING PARAMETERS

Instrument:	Perkin-Elmer 283 KBr plates or NaCl liquid cells	
	Survey	Rescan
Scan time (min) (4000 $cm^{-1} \rightarrow 250$ cm^{-1})	6	24
Vertical expansion	1X	2X or 5X
Slit	Normal	7
Response	1	2
Mode	% Transmission	Same

TABLE 16. FUNCTIONAL GROUP IDENTIFICATION USING INFRARED SPECTROSCOPY--TYPICAL SPECIES DETECTION LIMITS AND PEAK INTENSITIES

Compound class	Peak intensity	Suggested[d] detection limit ($\mu g/m^3$) for compound confirmation
Aldehydes	Strong C=O	40-50
	Weak C=O ↓ H	
Aliphatics[a,b]	Medium	50
Amides[a]	Strong	12-17
Alcohols[a]	Medium	NA[e]
Aromatics[a]	Strong <900 cm^{-1}	10-30
	Medium >900 cm^{-1}	
Carboxylic Acids[a,b]	Strong	23-37
Chlorinated Hydrocarbons[a]	Medium	NA[e]
Esters[a]	Strong	3
Ethers[c]	Strong	NA[e]
Ketones[a]	Medium	NA[e]
Nitro (NO_2) Compounds	Strong	30
Phenols	Medium	NA[e]
Phthalates	Strong	7

[a]This value was determined from an IR run in our laboratory. When actual laboratory data were unavailable, detection limits were determined from literature values of documented molar extinction coefficients. These were obtained from the following sources: (a) The Infrared Spectra of Complex Molecules, by L. J. Bellamy 2nd edition, John Wiley and Sons, New York 1952. (b) Infrared Absorption Spectroscopy - Practical, by Koji Nakanishi, Holdon-Day Inc., San Francisco, CA, 1962.

[b]This value is somewhat exaggerated, as it was derived from an IR spectrum of a GRAV residue.

[c]No information on IR absorption intensities or extinction coefficients of pure compounds was found.

[d]Above data assume a 30 m^3 flue gas sample collected under SASS train conditions extracted and concentrated to 10.0 ml prior to analysis.

[e]While detection of this functionality is possible, it is difficult to confirm.

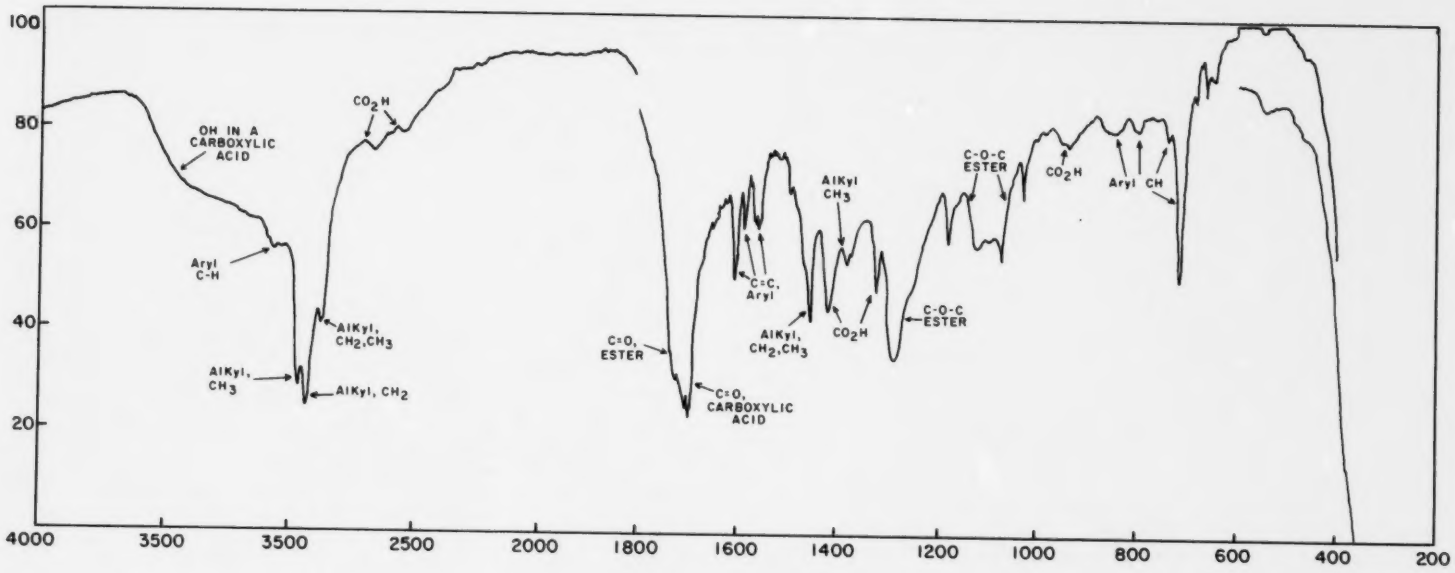

Figure 9. Typical IR scan of B&W/Alliance combustor flue gas stream samples (BW1-2-01-XM).

TABLE 17. PNA RESOLUTION AND SENSITIVITY PROFILE

Compound name	RRT Anthracene	Minimum detectable Conc. (pg/μℓ)
Naphthalene	0.562	660
Anthracene	1.00	11
Fluoranthene[a]	1.22	71
2-Methyl anthracene	1.45	74
Benz(a)anthracene[b]	1.77	0.80
Benzo(k)fluoranthene	2.41	0.81
Benzo(a)pyrene[c]	2.57	0.28
7,12-Dimethyl-benzanthracene[d]	2.88	0.67
1,2,5,6-Dibenzanthracene	3.05	0.57
Indeno(1,2,3-cd) pyrene	3.16	25
Benzo(ghi)perylene	3.32	0.91
Anthanthrene	3.07	1.0[e]
Coronene	4.62	0.15[f]

[a]Co-elutes with Pyrene.

[b]Co-elutes with Triphenylene and Chrysene.

[c]Co-elutes with Benzo(e)pyrene.

[d]Co-elutes with 1,2,3,4-Dibenzanthracene.

[e]Approximate.

[f]Using emission wavelength of 450 nm.

Prior to HPLC/Flu analysis an aliquist of each sample was filtered through a FH 0.5 µm Fluoropore filter and diluted with methanol. A 30 µl aliquist was then analyzed; operating conditions are outlined in Table 18.

Anthracene was added to each extract prior to analysis to act as an internal standard. All identifications were made from retention time data recorded relative to the internal standard. Quantitative data were calculated from calibration curves constructed for each of the PNA species. Standards were injected daily as a check on column resolution and detector sensitivity.

A typical chromatogram from HPLC/Fluorescence screening of sample extracts is depicted in Figure 10.

Bioassay Techniques

The phased IERL-RTP Environmental Assessment (EA) approach provides for specific chemical and biological tests. The chemical characterization of effluent or emission streams is necessary to define the need for and the possible types of control technology. However, the final objective of the EA methodology is the control of industrial emissions that may cause biological harm. Testing of feed or waste streams for biological (health and ecological) effects is necessary both to provide a direct measure of toxicity as well as to complement the chemical data and ensure that the assessment is comprehensive.

A biological test regimen has, therefore, been developed to provide some indication of potential health or environmental hazard. The Level 1 bioassay test scheme was created as an initial screening program. As such, the sensitivity and specificity of the tests prescribed are adequate only to point out some of the more hazardous emission streams associated with the processes under study. Level 1 bioassay are outlined in Figure 19 for multimedia samples and are briefly described in Table 19. Detailed protocols for the Level 1 bioassays used in this test program are based in those in the Level 1 Bioassay Manual.[3,4]

Health Effects Tests--

Microbial mutagenesis (Ames test)--The Ames mammalian microsome mutagenicity test using Salmonella typhimurium is one of the primary health effects screening tests incorporated into Level 1 of the IERL-Environmental Assessment methodology. The Ames assay system is used to determine the ability of effluent stream samples to alter the genetic material of a bacterial cell; it is a genetically well-characterized system and has been rather extensively validated as a test for detection of gene mutation. A detailed protocol for routine use of the assay system was published by Ames and co-workers in 1975.[5] Since that time, the assay system has gained wide acceptance and has been incorporated into testing regimens of both private industry and government agencies for a wide variety of samples.[6,7]

TABLE 18. INSTRUMENT OPERATING CONDITIONS - HPLC WITH FLUORESCENCE DETECTION

HPLC		Fluorescence
DuPont 850 HPLC w/ Gradient Elution		Perkin-Elmer 650-10S Detector
Column		Wavelength (nm)
Zorbax ODS 25.0 cm x 4.7 cm		Excitation 300
		Emission 400
Flow rate		Slit width 15 nm
1.5 mL/min.		Output 1 Volt to Spectra physics minigrator
Solvent	Methanol/water	
Step gradient		
% Methanol	Time (min.)	Chart speed 20 cm/hr.
1. 80-85	20	
2. 85-90	15	
3. 90 - HOLD	10	
4. 90-95	10	
Oven temperature	40°C	

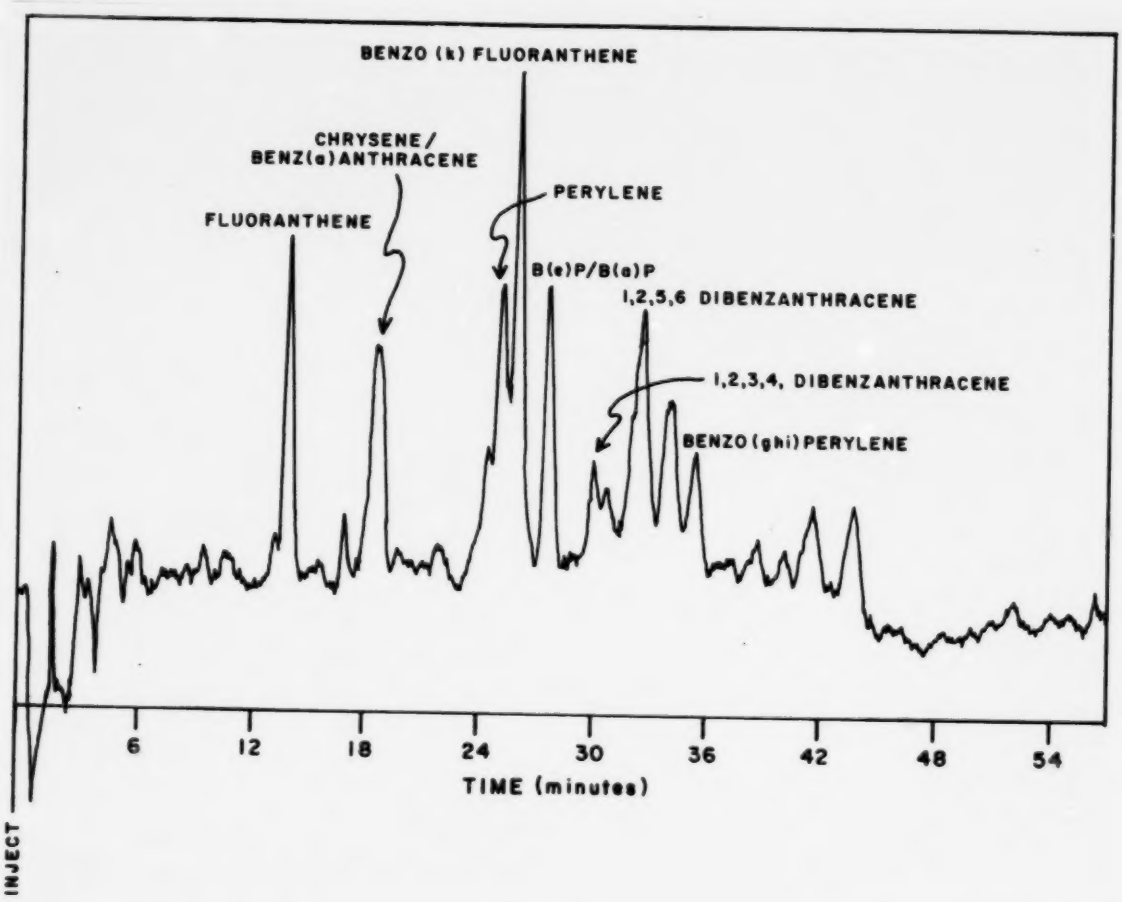

Figure 10. Typical HPLC/Fluorescence chromatogram.

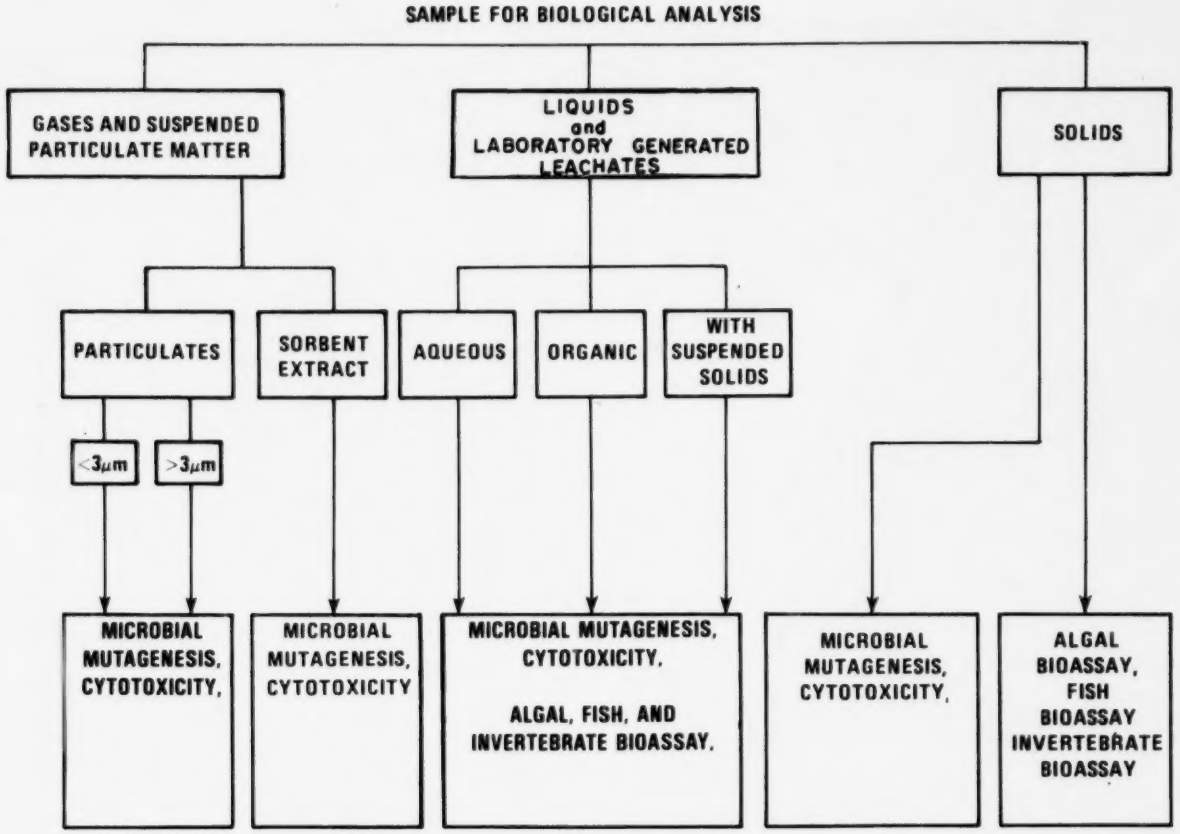

Figure 11. Biological analysis overview.

TABLE 19. LEVEL 1 SCREENING BIOASSAYS

Test	Effect	Description	Test outputs
Microbial Mutagenesis (Ames Test)	Mutagenesis	Genetically sensitive strains of microorganisms are exposed to various doses of sample with and without exogenous metabolic activation.	Mutagenic response is measured relative to controls.
Cytotoxicity	Cellular Toxicity	Selected cells (RAM and CHO) are exposed to various doses of sample, then metabolic and other endpoints are measured.	An index of functional impairment, toxicity, and metabolic change is established relative to controls.

ECOLOGICAL EFFECTS TESTS

Test	Effect	Description	Test outputs
Algal Growth Response	Algal Growth Inhibition or Promotion	Cultures of selected marine and/or freshwater algae are used to gage reaction to sample or dilution thereof.	Growth response measure-stimulation or inhibition.
Aquatic Animal Exposure (Static Acute Bioassay)	Animal Toxicity	Select marine and/or freshwater vertebrates and invertebrates are exposed to a graded dilution of samples.	Gross index of toxic potential to representative animals.

Description--The Ames assay system measures reverse mutations, both frame-shifts and base pair substitutions, in histidine-dependent strains of Salmonella that have been genetically engineered to increase their sensitivity and specificity. The tester strains are exposed to the test substance (mutagen) both in the presence and absence of mammalian metabolic activating enzymes. These enzymes convert many potential mutagens to their active form by mimicking in vivo conditions. The formation of bacterial colonies in a histidine-free medium after treatment is considered a criteria of the effectiveness of the test substance as a mutagen.

The Ames mammalian-microsome assay system is now extensively used as a primary screening test which is believed to provide a rapid, inexpensive method to pinpoint potentially carcinogenic substances to which man may be exposed. Based on the work of McCann et al.[6] and other investigators,[8-10] there appears to be a high correlation (85 to 90%) between those substances detected as mutagens in Salmonella typhimurium and carcinogenicity in mammals.

Level 1 criteria for a positive (mutagenic) response in the Ames test is a ratio of test revertants to control revertants greater than 2 for any tester strain (TA-1535, TA-1537, TA-1538, TA-98, or TA-100), plus an increasing dose/response relationship over three successive dose ranges.[3] Also, the experimental response must be reproducible run to run. The experimental procedure is discussed in detail elsewhere.[3,5]

Cytotoxicity assays (RAM and CHO)-- Level 1 cytotoxicity assays employ mammalian cell lines in culture to measure metabolic impairment and death resulting from in vitro exposure to toxicants. Rabbit alveolar macrophages (RAM) and Chinese hamster ovary (CHO) cells are the cell lines of choice.[3]

The alveolar macrophage represents a central line of pulmonary defense lining by virtue of its ability to engulf (phagocytize) and thus remove inhaled particles from the deep lung. This cell line is appropriate, therefore, to define the acute cellular toxicity of airborne particles and associated substances. Following exposure of the cells to the sample in vitro, four parameters are measured: total cell count, cell viability (assessed through trypan blue dye exclusion), total protein, and intracellular ATP concentration.

Although cytotoxic response in the RAM assay is important, the relative cytotoxicity of samples to other cell systems is of interest as well. In Level 1, a toxicity assay using the aneuploid Chinese hamster overy (CHO) cell line is now specified. This technique involves the plating of a specified number of cells on a tissue culture dish and subsequent exposure of the cells to the samples. Discrete "clonal" colonies of cells are allowed to grow. Plates are scored after this incubation period, and relative plating efficiency is calculated. This plating efficiency may be plotted as a function of exposure concentration of test material and a value analogous to an LC_{50} may be calculated.

Rodent Acute Toxicity Test--

This in vitro assay system is currently undergoing revision for Level 1 testing. At present, it appears mice will now be specified for testing in place of rats. This assay was not performed on B&W/Alliance samples.

Ecological Effects Tests

Although both freshwater and marine assays are specified for Level 1 use, only freshwater testing is believed to be relevant to assay of fluidized-bed combustion effluent samples. Discussion is, therefore, limited to these assays.

Freshwater Algal Assay--

The primary test alga in Level 1 is Selenastrum capricornutum. The test is designed to be used to quantify the biological response (algal growth) with respect to changes in concentrations of nutrients and to determine whether various effluents are toxic or inhibitory to algae. These measurements are made by adding a selected test alga to the test water and determining algal growth at appropriate intervals. An EC_{50} corresponding to growth inhibitation is calculated.

Acute Static Aquatic Bioassays with Freshwater Fish and Daphnia

The fathead minnow (Pimephales promelus) is the primary vertebrate used in all tests carried out under this protocol for the environmental assessment studies. The invertebrate choice is Daphnia magna, which should be used if additional toxicity data are desired or if it is impossible to use the fathead minnow. These representative aquatic organisms will integrate synergistic and antagonistic effects of all the components in the aqueous test sample over the duration of their exposure. The test is scored by the number of dead or affected organisms after a specified period, i.e., every 24 h after the beginning of the test. More frequent observations may be desirable, expecially at the beginning of the test. Fathead minnow tests run for 96 hours; Daphnia tests run for 48 hours. An LC_{50} is calculated for fathead minnows. An EC_{50} is calculated for Daphnia. The effect used to determine the EC_{50} for Daphnia is immobilization, that is, lack of movement except for minor activity of appendages.

Terrestrial Ecology Tests--

Terrestrial bioassays have been developed relatively recently. Several assay systems are currently under review by IERL and their status is subject to change. Among the tests being considered for inclusion in the Level 1 bioassay test regimen are: a modified stress ethylene test designed for assessment of gaseous industrial emissions; a seedling germination test; and a short term insect toxicity test employing Drosophila melanogaster. No terrestrial assays were included in this source test evaluation.

Table 20 describes the Level 1 bioassays as performed on designated B&W/Alliance stream samples.

TABLE 20. BIOASSAY TESTING OF B&W/ALLIANCE SAMPLES

Sample description	Health effects testing			Ecological Effects testing		
	Ames	RAM	CHO	Fish	Daphnids	Algae
Combustor flue gas						
SASS Fine (<3 μm) particles (BW1-1-01-FC)	✓[a]	✓	-	-	-	-
SASS Coarse (>3 μm) particles (BW1-1-01-CC)	✓	✓	-	-	-	-
SASS XAD Extract (BW1-1-01-XM)	✓	-[b]	✓	-	-	-
Bulk solids	✓	✓	✓	✓[c]	✓[c]	✓[c]
Cyclone catch (BW1-1-03-CP)						
Spent bed material (BW1-1-04-CB)	✓	✓	✓	✓[c]	✓[c]	✓[c]

[a](✓) - indicates this assay was performed on the sample indicated.

[b](-) - indicates this assay was not performed.

[c]Ecological effects testing was performed on laboratory-generated distilled water leachates of these two bulk solid streams.

SECTION 5

TEST RESULTS

Test data were evaluated in conjunction with the methodologies which have been developed by IERL-RTP for their EA programs. If comparisons between and among sets of data from EA or other projects are to be of maximum benefit, such comparisons need to employ a standardized format. This format is provided by using a Source Analysis Model (SAM) coupled with the Multimedia Environmental Goal (MEG) methodology.

METHODOLOGIES

SAM/1A and the MEG Methodology

The MEG methodology[11] provides a means of summarizing health and ecological effects data. The MEG chart, as depicted in Figure 12, provides a workable system for evaluating discharged pollutants for the purpose of environmental assessment.

The MEG format can aid in evaluation of current environmental background for a pollutant and can help in environmental objectives development as well as in selection and application of assessment alternatives. This latter function of the MEG methodology is accomplished by establishing emission level goals (specifically, Discharge Multimedia Environmental Goals (DMEGs)). DMEGs are derived from a series of models which employ experimental toxicity data or existing Federal or other standards and criteria, specific for each pollutant for which a MEG chart has been formulated. Comparison of the discharged concentration of a pollutant species from a source with its DMEG provides decision criteria for further environmental data acquisition (that is, a "trigger" to go from Level 1 to Level 2 analytical effort), as well as a means of environmental alternatives analysis when the DMEGs are used in conjunction with a Source Analysis Model. Through the use of this model, effluent or emission streams may be ranked by potential toxicity to man or the environment. This assessment of priorities is important in deciding if and to what extent further, more intensive sampling and analysis is required, and it can help determine the need for, and in some cases the design of, appropriate control technology.

Level 1 survey results are assessed in terms of MEG compound categories and the individual DMEG values corresponding to each individual pollutant species. These values are incorporated into Source Analysis Model/1A (SAM/1A).[12] SAM/1A establishes a degree of hazard (called Discharge Severity (DS)) for each substance within an effluent stream as well as a value for the total

MULTIMEDIA ENVIRONMENTAL GOALS

EMISSION LEVEL GOALS							
	I. Based on Best Technology		II. Based on Ambient Factors				
Category	A. Existing Standards	B. Developing Technology	A. Discharge Multimedia Environ. Goal		B. Ambient Level Goal*		C. Elimination of Discharge
	NSPS, BPT, BAT	Engineering Estimates (R&D Goals)	Based on Health Effects	Based on Ecological Effects	Based on Health Effects	Based on Ecological Effects	Natural Background*
Air, $\mu g/m^3$ (ppm Vol)							
Water, $\mu g/l$ (ppm Wt)							
Land, $\mu g/g$ (ppm Wt)							

*To be multiplied by dilution factor

AMBIENT LEVEL GOALS					
	I. Current or Proposed Ambient Standards or Criteria		II. Toxicity Based Estimated Permissible Concentration		III. Zero Threshold Pollutants Estimated Permissible Concentration
	A. Based on Health Effects	B. Based on Ecological Effects	A. Based on Health Effects	B. Based on Ecological Effects	Based on Health Effects
Air, $\mu g/m^3$ (ppm Vol)					
Water, $\mu g/l$ (ppm Wt)					
Land, $\mu g/g$ (ppm Wt)					

Figure 12. Current version of the MEG chart.[11]

stream, thus providing a mechanism for the ranking of streams by potential hazard as mentioned above. A degree of hazard may be established to reflect both human health and the ecological domain.

SAM/1A is a model which provides a rapid screening technique for assessing the pollution potential of multimedia process or waste streams. There are a number of simplifying assumptions implicit in the use of SAM/1A:

- Only pollutant species for which a DMEG value has been derived need be considered when assessing a pollutant stream. It is also assumed that the DMEG values are adequate for estimating acute toxicity.

- Effluent streams from any process to which the model is applied are assumed not to interact with the external environment. That is, transport of the components in the effluent stream to the external environment occurs without chemical or physical transformation of those components.

- Although no assumption is made about pollutant dispersion, it is implied within the context of the model that such dispersion from the source would, in almost all cases, be equal to or greater than the safety factors normally applied to acute toxicity data to convert them to estimated safe chronic exposure levels.

These assumptions, along with the limited target accuracy of Level 1 test data and assumptions made in developing the DMEG values (see Reference 11) have to be considered when interpreting test results using SAM/1A. It is worth emphasizing that the weighted discharge severity sums, by which streams are ranked by "toxicity" using SAM/1A, are only useful within the context of the model and should not be misconstrued to represent a true numerical or other measure of potential toxicity to human health or the environment.

The basic steps included in SAM/1A are as follows.

- The specific pollutant species to be considered in each effluent stream under study and the concentration of such species within the stream (from Level 1 analytical data) are determined.

- Pollutant concentrations are divided by the DMEG value specific for that species. This ratio is designated "Discharge Severity (DS)." DS values are indicative of the contribution of each specific pollutant within the stream to the total calculated hazard factor representative of that stream.

- The product of the DS for each species within the stream and the stream flow rate is taken and designated "Weighted Discharge Severity (WDS)."

- The total effluent stream Discharge Severity is calculated by summing all of the individual DS values for substances in that stream. Also, the total stream WDS is calculated by summing the individual pollutant WDSs. These resulting dimensionless sums may be used to compare emission or effluent streams within a facility or among facilities. When Weighted Discharge Severity Sums are calculated for all streams exiting a facility and totaled, this value may then be used to compare calculated total degrees of hazard representing other facilities or other processes. In this manner sources may be ranked according to the levels of potentially toxic substances in their effluent discharges.

For this source test evaluation, the SAM/1A/DMEG methodology was used specifically to "flag" those trace elements which exceeded their respective emission goals (i.e., DS 1.0) in samples analyzed by SSMS and AA. Because of the very low organic content of B&W/Alliance samples analyzed, organic analytic data were not included in the SAM/1A analysis. Inclusion of these organic data would have resulted in an overestimation of the contribution of organic species to potential hazards associated with these samples. While Discharge Severity was calculated for trace elements in each sample, WDS and WDS sums were not, since any contribution to these totals from organic species was not incorporated. Organic data handling and interpretation is described below.

B&W/Alliance Organic Data Handling and Interpretation

Initial review of the organic analytical data revealed that only the SASS organic module (XAD) from the combustor flue gas stream contained sufficient organic material to require Liquid Chromatographic (LC) fractionation according to Level 1 criteria.* Organic content of solid streams samples was so low (on a µg/g basis) (see Table 21) that discussion of these results would suffer from overinterpretation of the limited data which was generated. Accordingly, analysis and interpretation of B&W/Alliance organic data involve only the combustor flue gas stream.

As noted in Table 21, TCO and GRAV analysis showed that combustor flue gas XAD (BW1-1-01-XM and BW1-2-01-XM) exceeded the 15 mg (TCO and GRAV total) trigger which mandates LC fractionation and subsequent analysis of fractions. The Day 2 sample was LC-fractionated (BW1-2-01-XM), while 70 percent of the Day 1 sample was required for bioassay.

The objective of the LC procedure is to separate the sample into fractions of various, discrete chemical classes to aid in further analysis which might eventually provide information leading to identification of organic species

*TCO and GRAV data revealed that BW1-1-05 and BW1-2-05, the coal feed streams, also required LC fractionation according to Level 1 criteria. Coal feed samples were fractionated, but no further chemical analyses were performed.

TABLE 21. TCO AND GRAV RESULTS - B&W/ALLIANCE STREAM SAMPLES

Sample description	Analytical results				
	TCO	GRAV	Totals		
	(μg)	(μg)	(μg)	(μg/g)	(μg/m³)
Combustor flue gas - Day 1 (26.3dscm)					
SASS Coarse (>3μm) particles	not analyzed	<Blank	-	-	-
SASS Fine (<3μm) particles	not analyzed	727	727[d]	-	28
SASS Organic module[a]	2970	20290	23260[d]	-	885
SASS Composite sample[b]	4	684	688	-	26
Total - flue gas stream	2974	21701	24675	-	939
Combustor flue gas - Day 2 (28.2 dscm)					
SASS Coarse (>3μm) particles	not analyzed	<Blank	-	-	-
SASS Fine (<3μm) particles	not analyzed	852	852	-	30
SASS Organic module	3390	13210	16600[d]	-	588
SASS Composite sample	4	622	626	-	22
Total - flue gas stream	3394	14684	18078	-	640
Bulk solids					
Combustor cyclone catch - Day 2	458	350	808	1.6	-
Spent combustor bed material - Day 2	13	5290	5303	7.6	-
Coal feed - Day 1 (mg)	70	233	303	3.0	-
Coal feed - Day 2 (mg)	48	188	236	2.4	-

[a]Comprises XAD-2 resin extract plus module rinse.

[b]Comprises SASS train condensate. Probe rinse was not analyzed because the sample did not meet Level 1 criteria.

[c]Sorbent feed stream not analyzed. Day 1 results for cyclone catch and spent bed were similar to these reported for Day 2.

[d]Requires liquid chromatographic separation and subsequent analysis of fractions according to Level 1 criteria (>15 mg total TCO and GRAV).

present. However, the LC procedure used in Level 1 is not a high resolution technique; the seven LC fractions obtained by following the Level 1 procedure represent only a gross separation, and there is broad overlap in class type between many of the fractions.

The results of the LC fractionation procedure include quantitative estimates of TCO and GRAV range organic materials in each of the seven fractions. These values were converted to equivalent concentrations at the source (in $\mu g/m^3$) for easy comparison of LC results with DMEG decision criteria. Data obtained from onsite gas chromatography (GC) for low boiling point organics were also converted in this manner for comparison with DMEGs.

A survey was made of those organic compounds potentially present in both LC and GC fractions for which DMEG values have been adopted based on information provided in Harris, et al.[13] These compounds were categorized as potentially present in GC (gaseous), TCO (volatile), or GRAV (nonvolatile) boiling point ranges. This review resulted in a list of candidate compounds for both GC and LC TCO or GRAV data. By assuming that the total emissions of organic species within a fraction consisted solely of that candidiate compound with the lowest DMEG, organic compounds of potential concern could be determined. The accuracy or plausibility of such identifications must be contrasted with the previously recognized limitations of the Level 1 LC fractionation scheme.

Handling of B&W/Alliance organic data may be summarized as follows:

- Initial Level 1 organic data were compiled. These data included totals for volatile species (TCO--Total Chromatographable Organics), nonvolatile species (GRAV--Gravimetric), and onsite GC spectra where applicable. Such values were represented as $\mu g/g$ or $\mu g/m^3$, depending on the emission goal (DMEG) to be applied.

- A survey was made of all DMEG values that have been adopted for organic compounds or classes of compounds (586 to date).[14]

- The assumption was made that the total weight of organics present in the sample analyzed was representative of one compound, as a worst case, and all species whose DMEG was lower than this total were listed. This exercise resulted (for some samples) in a list of compounds of potential concern. In other samples, this listing resulted in elimination of organic compounds as an area of concern for future investigation.

- Organic compounds of concern were then reviewed based on knowledge of process chemistry, operating conditions, and the available Level 1 bioassay results. This review enabled elinimation of some species which could not possibly be present in these FBC emission streams.

- A final list (on a stream-by-stream basis) of organic compounds of potential concern was compiled.

Bioassay Data Analysis

Bioassay test results were characterized according to the degree of response which is defined using the criteria that have been established by IERL-RTP for Level 1 bioassay.[3,4] These criteria are listed in Table 22. Bioassay test results are included with SAM/1A analysis of the inorganic chemical data and results of organic data analysis to aid in ranking the streams analyzed at B&W/Alliance by order of priority for further testing.

ANALYTICAL RESULTS

Onsite Analyses

As described in Sections 3 and 4, onsite sampling and analysis were limited to determination of fixed gases, sulfur species, ammonia and cyanide, and volatile organics (bp $\leq$100°C) in combustor flue gases.

Fixed Gases

Results of GC/TCD analysis of two combustor flue gas grab samples for CO_2, O_2, and N_2 are summarized in Table 23. The value for CO is based on analysis by Kitagawa tube as discussed in Section 4.

Sulfur Species

Table 24 summarizes results of analysis of evacuated flask samples for sulfur species onsite by GC/FPD.

Reduced Nitrogen

No cyanide was detected in the field analysis of flue gas samples by the colorimetric pyridine-pyrazolone method (Hach kit).

Direct nesslerization of the ammonia samples was not possible due to an interference resulting in high turbidity upon the addition of the Nessler's reagent. Attempts at removing the interference by complexation or precipitation were unsuccessful. The samples were preserved with concentrated sulfuric acid and analyzed at GCA by ion chromatography.

INORGANIC ANALYTIC RESULTS

Level 1 inorganic laboratory analysis involves quantification of trace elements and certain anionic species in solid samples and laboratory-generated distilled water leachates using SSMS, AA, and wet chemical techniques (IC).

Trace Elemental Analyses by SSMS and AA

Combustor Flue Gas--

Trace elements were quantified in B&W/Alliance combustor flue gas samples by SSMS and AA (for Hg, Sb, and As) analysis of SASS train components. Complete data are included in Appendix A. SAM/1A analysis of trace element data for flue gas samples is summarized in Table 25. The measured concentration

TABLE 22. RESPONSE RANGES FOR RANKING OF VARIOUS BIOTESTS

Assay	Activity measured	MAD	Response ranges			
			High	Moderate	Low	Not detectable
Health tests						
Ames	Mutagenesis	5 mg/plate or 500 µL/plate	<0.05 mg or <5 µL	0.05-0.5 mg or 5.50 µL	0.05-5 mg or 50-500 µL	ND at>5 mg or ND at>500
RAM, CHO	Lethality (LC_{50})	1,000 µg/mL or 600 µL/mL	<10 µg or <6 µL	10-100 µg or 6-60 µL	100-1,000 µg or 60-600 µL	LC_{50}>1,000 µg or LC_{50}>600 µL
Ecological tests						
Algae	Growth inhibition (EC_{50})	1,000 mg/L or 100%	<20% or <200 mg	20-75% or 200-750 mg	75-100% or 750-1,000 mg	EC_{50}>100% or EC_{50}>1,000 mg
Fish	Lethality (LC_{50})	1,000 mg/L or 100%	<20% or <200 mg	20-75% or 200-750 mg	75-100% or 750-1,000 mg	LC_{50}>100% or LC_{50}>1,000 mg
Invertebrate	Lethality (LC_{50})	1,000 mg/L or 100%	<20% or <200 mg	20-75% or 200-750 mg	75-100% or 750-1,000 mg	LC_{50}>100% or LC_{50}>1,000 mg

MAD = Maximum applicable dose (technical limitations).

LC_{50} = Calculated concentration expected to kill 50% of population.

EC_{50} = Calculated concentration expected to produce effect in 50% of population.

ND = Not detectable.

TABLE 23. ONSITE FIXED GAS ANALYSIS OF B&W/ALLIANCE INTEGRATED BAG SAMPLES (%)

Analysis date	CO_2	O_2	N_2	CO
12/10/79	14.3	5.9	78.6	0.02
12/12/79	14.9	3.9	77.3	0.02

[a]240 ppm by Kitagawa tube = 0.02% by volume.

TABLE 24. ONSITE GC ANALYSIS OF B&W/ALLIANCE FLUE GAS SAMPLES FOR SULFUR SPECIES

Sulfur species	Date of analysis				
	12/10	12/11	12/12[a]	12/12	12/13
H_2S	<10	<10	<10	<10	<10
COS	<10	<10	<10	<10	<10
MMC[c]	<10	<10	<10	<10	<10
SO_2	523	619	428	68	224
		833		272	514
					321

[a]Analyses on 12/12 were conducted in two separate parts.

[b]Minimum detectable concentration is 10 ppm for these analyses. All values listed as <10 ppm are actually below the detection limit of the GC.

[c]MMC = Methyl mercaptan.

TABLE 25. SAM/1A INORGANIC TRACE ELEMENT ANALYSIS OF B&W/ALLIANCE FLUE GAS STREAM SAMPLES

Element	Emission Goal (DMEG) (µg/m³) Health	Ecology	Calculated Discharge Severity (DS)[a] in Flue Gas Samples[b] (BW1-1-01) Health	Ecology	(BW1-2-01) Health	Ecology
Lithium	22		(50)		(43)	
Beryllium	2		(50)		(33)	
Boron	3,100		(7)		(11)	
Fluorine	1,000		(16)		(13)	
Sodium	53,000		(1.9)		0.23	
Magnesium	6,000		(10)		4	
Aluminum	5,200		(7)		(75)	
Silicon	10,000		4		(82)	
Phosphorus	100		(180)		(140)	
Sulfur	-		-		-	
Chloride	-		-		-	
Potassium	-		-		-	
Calcium	16,000		(2)		(2)	
Scandium	53,000		<0.01		<0.01	
Titanium	6,000		(13)		(11)	
Vanadium	500	1.0	(6)	(3,000)	(5)	(2,400)
Chromium	1		(1,800)		(2,300)	
Manganese	5,000		(3)		(1)	
Iron	1,000		(38)		(32)	
Cobalt	50		(12)		(16)	
Nickel	15		(227)		(233)	
Copper	200		(9.5)		(4)	
Zinc	4,000		0.58		0.20	
Gallium	5,000		0.11		0.05	
Germanium	560		0.29		0.15	
Selenium	200		(2)		(2)	
Bromine	-		-		-	
Rubidium	120,000		<0.01		<0.01	
Strontium	3100		(2)		(3)	
Yttrium	1000		0.97		(1)	
Zirconium	5000		0.54		0.38	
Niobium	22,000		0.02		<0.01	
Molybdenum	5000		0.02		0.04	
Ruthenium	-		-		-	
Rhodium	1		No Data		(<23[d])	
Palladium	-		-		-	

Element	Emission Goal (DMEG) (µg/m³) Health	Ecology	Calculated Discharge Severity (DS) in Flue Gas Samples (BW1-1-01) Health	Ecology	(BW1-2-01) Health	Ecology
Cadmium	10		(2)		(2)	
Tin	-		-		-	
Antimony	500		0.07		0.09	
Tellurium	100		<0.39		<0.63	
Iodine	-		-		-	
Cesium	82,000		<0.01		<0.01	
Barium	500		(19)		(11)	
Lanthanum	110,000		<0.01		<0.01	
Cerium	37,000		<0.01		<0.01	
Praseodynium	51,000		<0.01		<0.01	
Neodynium	-		-		-	
Samarium	53,000		<0.01		<0.01	
Europium	-		-		-	
Gadolinium	-		-		-	
Terbium	-		-		-	
Dysprosium	9,300		<0.01		<0.01	
Holmium	-		-		-	
Erbium	-		-		-	
Thulium	-		-		-	
Ytterbium	1,000		<0.01		0.05	
Lutetium	-		-		-	
Hoffnium	500		<0.36		0.56	
Tungsten	1,000		<0.14		<0.06	
Rhenium	-		-		-	
Osmium	-		-		-	
Iridium	-		-		-	
Gold	-		-		-	
Thallium	100		0.38		0.67	
Lead	150		(6)		(5)	
Bismuth	410		0.08		0.13	
Thorium	420		0.14		0.24	
Uranium	9		(6)		(10)	
Mercury[g]	50	10	0.5	(3)		(3)
Antimony[g]	500	-	<0.001		<0.001	
Arsenic	2	-	<0.2	-	<0.2	-

[a] Discharge Severity = $\frac{\text{Measured Elemental Concentration}}{\text{Air DMEG}}$.

Elements whose DS ≥ 1.0 are circled.

[b] Indicated flue gas concentrations are based on the total concentration measured in all SASS train components. Complete data are in Appendix A.

[c] Hg, Sb, and As were measured using AA; all other data are from SSMS.

[d] Since Rh concentration is characterized as "less than," Rh is assumed not to exceed its goal.

Elements Exceeding Their Air DMEG

BW1-1-01 Li, Be, B, F, Na[e], Mg, Al, Si, P, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Se, Sr, Cd, Ba, Pb, U, Hg.

BW1-2-01 Li, Be, B, F, Mg, Al, Si, P, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Se, Sr, Y[f], Cd, Ba, Pb, U, Hg[g]

[e] Exceeds health DMEG only in Day 1 samples.

[f] Exceeds health DMEG only in Day 2 samples.

[g] Exceeds ecological DMEG in both Day 1 and Day 2 samples.

[h] These elements would exceed their air DMEGs even if 99.9 percent of flue gas particles were captured by control devices. Chromium exceeds its health and vanadium its ecological DMEG.

used in DS calculation represent the total elemental concentration measured in all SASS train components (see Appendix A). These data were compared to air Discharge Multimedia Environmental Goals (DMEG). Discharge Severity (DS), was calculated and is listed for each. Twenty-five elements exceed one or both air DMEGs in flue gas stream samples. Vanadium exceeds only ecological goals in each. Sodium exceeds its health goal in Day 1 samples but not for Day 2. The converse is true for Yttrium. The remaining 21 flagged elements are flagged in both streams.

It is difficult to draw any conclusions about potential hazards to health or the environment for B&W/Alliance combustor flue gas based on these data. Sampling of the flue gas stream, as described in Section 3, occurred prior to any particle control devices. Therefore, dust loading in the flue gas was extremely heavy (approximately 35-40 g/m^3). Comparison of data from analysis of flue gas samples with air DMEGs, which are expressed as $\mu g/m^3$, exaggerates the potential hazard associated with this stream. A better assessment of the hazards associated with this stream may be obtained in two ways. A reevaluation of these data may be made by assuming particulate control operating at an efficiency sufficient to meet New Source Performance Standards (NSPS) for emission of particles for Utility Boilers. To meet the present NSPS of 0.03 lb particles/10 Btu, 99.9 percent of the particles in the flue gas stream would have to be collected prior to release of the flue gas to the atmosphere. This collection efficiency is within the capability of conventional particulate control devices. If this level of particle control is assumed, only two elements would exceed their air DMEG. Chromium exceeds its health goal and vanadium its ecological goal. It must be pointed out, however, that evaluation of these data in this manner is an oversimplification and ignores possible effects of varying particle sizes, potential concentration of some species on smaller particles, etc.

If virtually 100 percent of the flue gas particulate matter is assumed captured, this material may be considered to be a solid waste material which would be relegated to disposal in a landfill or other area. Accordingly, trace elemental concentrations data were converted to a $\mu g/g$ basis and compared to appropriate land DMEGs.

Table 26 compares measured elemental concentrations in flue gas particles with appropriate land DMEGs. Elements listed are only those which exceeded air DMEGs in the flue gas stream. Even though comparison of elemental concentrations of flue gas particles with land DMEGs is valid, judgements were still necessary in some cases. In many instances, elemental concentrations were so high that accurate quantification using SSMS was not practical. These concentrations are indicated as "greater than" in Table 26. Whether these elements exceed their emissions goals is, as in the case of titanium, clear. Evaluation of data for elements such as calcium, however, is not as easy.

Based on our interpretations, eleven trace elements in flue gas particles exceed land DMEGs and are thus potential candidates for Level 2 investigation. These elements are aluminum, phosphorus, titanium, vanadium, manganese, iron, nickel, copper, selenium, cadmium and lead. Of these, phosphorus may be relegated to a low priority. The stringent ecological DMEG for phosphorus (0.1 $\mu g/g$, is derived from the toxicity of elemental phosphorus. This species could not possibly be present in FBC flue gas.

TABLE 26. TRACE ELEMENTS EXCEEDING AIR DMEGs IN FLUE GAS SAMPLES COMPARED WITH LAND DMEGs

	DMEG (µg/g)		Concentration[a] (µg/g)	
	Health	Ecology	Day 1	Day 2
Lithium	70	75	30	28
Beryllium	6	11	3	2
Boron	9,300	5,000	590	1,031
Fluorine	7,500	N[b]	1,115	1,019
Sodium	160,000	N	>1,450[c]	-[d]
Magnesium	18,000	17,000	>1,160	807
Aluminum	16,000	200	>2,000[c]	>2,000[c]
Silicon	30,000	N	>2,000[c]	>1,580[c]
Phosphorus	3,000	0.1	476	432
Calcium	48,000	3,200	>2,000[c]	>2,000[c]
Titanium	18,000	160	>1,950	>1,320
Vanadium	500	30	78	72
Chromium	50	50	19	39
Manganese	50	20	369	193
Iron	300	50	>2,000[c]	>2,000[c]
Cobalt	150	50	15	23
Nickel	45	2	59	73
Copper	1,000	10	50	25
Selenium	10	5	11	12
Strontium	9,200	N	187	298
Yttrium	3,000	N	-	34
Cadmium	10	0.2	0.4	>0.5
Barium	1,000	500	256	171
Lead	50	10	25	21
Uranium	12,000	N	>2	>3
Mercury	20,000	50	0.8	0.8

[a] Concentrations represent only those in flue gas particles.

[b] N indicates no goal has been adopted.

[c] These values may only be indicated as "greater than" because of their large concentration (>10 percent total sample) in some SASS train components - see text.

[d] - indicates this element did not exceed air DMEGs in this sample.

Bulk Solids--

Table 27 lists calculated DS values for trace element concentrations measured in B&W/Alliance bulk solid samples. Table 28 summarizes results by listing all elements exceeding their respective land DMEG in both feed streams and solid waste streams. Sixteen elements exceed one or both DMEGs in one or more samples. Day 1 and Day 2 samples were consistent for spent bed material and sorbent; some variation between Day 1 and Day 2 was observed in elements flagged in cyclone ash.

Quantification of trace elements in bulk solid streams and comparison with land DMEGs is a method designed to provide a measure of potential adverse impacts on human health or the environment due to leaching of these materials following disposal in a landfill or other area. Our experience has indicated that this methodology does not provide a consistent measure of hazard potential. Rather, we believe a better assessment of FBC bulk solid waste streams is obtained by generation of laboratory leachates and subsequent screening by SSMS used in conjunction with graphite furnace AA to better quantify species of interest.

Table 29 summarizes SAM/IA analysis of the laboratory-generated leachates of the two B&W/Alliance solid waste streams. SSMS data reveal only two elements exceeding their emission goals. Phosphorus may be dropped from consideration since the DMEG is derived based on toxicity data relevant to elemental phosphorus, as previously discussed. Calcium consistently exceeds its DMEGs both in bulk solid samples and leachates generated from these samples. Large calcium concentrations are undoubtedly due to contributions to these waste streams from sorbent material.

Graphite furnace AA was used to quantify ten metals in these samples. These species are of special interest because of their toxicity (especially to aquatic species), as evidenced by their strigent emission goals. AA data showed that nickel and selenium exceeded water DMEGs in both bulk solid waste streams and vanadium exceeded ecological goals in cyclone ash.

Another method of assessing the potential hazards associated with leaching of these solid waste materials is through comparison, where possible, between B&W/Alliance AA data and the limits promulgated by the EPA Office of Solid Waste (DSW) for identification of hazardous solid wastes. Table 28 lists the species which can be compared in this manner. OSW limits reflect a safety factor of 100 times the limits set in EPA National Interim Primary Drinking Water Standards. This safety factor is assumed to reflect dilution of these species as the solid waste is leached from a disposal area and leachate potentially enters groundwater. Data in Table 30 indicate that levels of toxic metals leached from B&W/Alliance bulk solid waste streams are well below these OSW limits.

Ion Chromatography Results

B&W/Alliance leachates were analyzed by ion chromatography (see Section 4) to quantify certain anionic species. Results are listed in Table 31. Since no DMEGs have been adopted for these species, results are compared to 100 times drinking water standards to incorporate the dilution factor cited above and

TABLE 27. SAM/1A INORGANIC TRACE ELEMENT ANALYSIS OF B&W/ALLIANCE BULK SOLID SAMPLES

Element	Emission goal (DMEG) (µg/g) Health	Ecology	Discharge severity (DS)[b] for trace elements in bulk solid streams: Combustion cyclone solids (BW1-1-03-CP) Health	Ecology	(BW-1-2-03-CP) Health	Ecology	Combustion bed material (BW-1-1-04-CB) Health	Ecology	(BW-1-2-04-CB) Health	Ecology	Coal Feed[c] (BW1-2-05-CF) Health	Ecology	Sorbent feed (BW1-1-06-LF) Health	Ecology	(BW1-2-06-LF) Health	Ecology
Lithium	70	75	0.02	0.02	0.37	0.35	0.09	0.09	0.05	0.04	0.05	0.04	<0.01	<0.01	<0.01	<0.01
Beryllium	6	11	<0.01	<0.01	0.15	0.08	0.30	0.16	0.15	0.08	0.08	0.04	<0.01	<0.01	<0.01	<0.01
Boron	9,300	5,000	0.01	0.01	0.02	0.05	0.05	0.10	0.01	0.06	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fluorine	7,500	-	0.02	-	0.03	-	0.13	-	0.03	-	<0.01	<0.01	0.02	-	0.07	-
Sodium	160,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	<0.01	<0.01	-	<0.01	-
Magnesium	18,000	17,000	0.04	0.04	0.08	0.09	0.08	0.08	0.08	0.04	0.04	0.01	0.04	0.04	0.83	0.88
Aluminum	16,000	200	0.01	0.75	(1.1)	(90)	0.03	(2.7)	0.04	(3)	6	(<500)	0.13	(11)	0.02	(1.3)
Silicon	30,000	-	0.40	-	0.77	-	0.77	-	0.21	-	(1.1)	-	0.30	-	0.20	-
Phosphorus	3,000	0.1	0.07	(2,000)	0.13	(4,000)	0.53	(6,000)	0.13	(4,000)	0.02	(550)	0.07	(2,000)	0.13	(3,900)
Sulfur	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloride	240,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Potassium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calcium	48,000	3,200	(>2)	(>31)	(>2)	(>31)	(>2)	(>31)	(>2)	(>31)	<0.01	0.09	(>2)	(>31)	(>2)	(>31)
Scandium	160,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Titanium	18,000	160	0.09	(10)	0.09	(10)	0.04	(4.8)	0.02	(2.4)	0.01	(1.5)	<0.01	0.6	<0.01	(1.2)
Vanadium	500	30	0.13	(2.2)	0.26	(4.4)	0.06	(1.0)	0.06	(1.0)	0.02	0.25	0.02	0.26	0.02	0.26
Chromium	50	50	(2)	(2)	0.30	0.30	0.15	0.08	0.15	0.08	0.08	0.08	0.01	0.01	0.02	0.02
Manganese	50	20	(7)	(18)	(7.2)	(18)	(14)	(36)	(14)	(36)	0.08	0.19	(7)	(18)	(7)	(18)
Iron	300	50	(200)	(1,200)	(200)	(1,200)	(50)	(300)	(25)	(150)	(12)	(70)	(25)	(300)	(25)	(300)
Cobalt	150	50	0.07	0.22	0.04	0.11	0.02	0.06	0.01	0.03	0.01	0.02	0.02	0.06	0.11	0.33
Nickel	45	2	(2.9)	(65)	0.36	(8)	0.71	(16)	0.35	(8)	0.04	(1.0)	0.36	(8)	0.36	(8)
Copper	1,000	10	0.02	(2.1)	0.02	(2.2)	<0.01	0.53	<0.01	0.62	<0.01	0.97	<0.01	0.13	<0.01	0.27
Zinc	5,000	20	<0.01	0.95	0.01	(1.9)	<0.01	0.95	<0.01	0.95	<0.01	0.50	<0.01	0.27	<0.01	0.27
Gallium	15,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Germanium	1,700	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Arsenic	50	10	0.66	(3.3)	0.68	(3.4)	0.66	(3.3)	(1.3)	(6.7)	0.17	0.83	0.08	0.41	0.04	0.21
Selenium	10	5	0.40	0.80	(7.4)	(15)	(3.7)	(7.4)	(15)	(30)	0.40	0.80	(3.7)	(7.4)	(7.4)	(15)
Bromine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rubidium	360,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Strontium	9,200	-	0.12	-	0.06	-	0.06	-	0.12	-	<0.01	-	<0.01	-	<0.01	-
Yttrium	3,000	-	0.02	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Zirconium	1,500	-	0.09	-	0.04	-	<0.01	-	0.02	-	<0.01	-	<0.01	-	<0.01	-
Niobium	65,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Molybdenum	15,000	1,400	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Ruthenium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhodium	3	-	<0.05	-	<0.11	-	0.10	-	<0.05	-	No Data	-	<0.01	-	<0.05	-
Palladium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cadmium	10	0.2	0.16	0.08	<0.02	<0.01	0.08	0.04	<0.01	<0.01	0.04	0.02	<0.01	<0.01	<0.01	<0.01
Tin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Antimony	15	40	0.09	0.03	0.09	0.03	0.87	0.33	0.04	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tellurium	300	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Iodine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cesium	250,000	1,200,000	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Barium	1,000	500	0.56	(1.1)	0.13	0.26	0.27	0.54	0.07	0.14	0.02	0.04	0.14	0.28	0.07	0.14
Lanthanum	340,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Cerium	110,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Praseodymium	150,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Neodymium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Samarium	160,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Europium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gadolinium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Terbium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dysprosium	46,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Holmium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erbium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thulium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ytterbium	3,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Lutetium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hafnium	150	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Tungsten	3,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Rhenium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Osmium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Iridium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gold	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thallium	300	-	0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Lead	50	10	0.54	(2.7)	0.30	(1.5)	0.14	0.70	0.07	0.35	0.09	0.45	0.03	0.18	0.02	0.09
Bismuth	1,200	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Thorium	130	-	0.11	-	0.03	-	0.01	-	0.01	-	0.13	-	<0.01	-	<0.01	-
Uranium	12,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Mercury[a]	2	50	-	-	-	-	-	-	-	-	0.04	<0.01	-	-	-	-

[a] Hg was quantified by AA - all others by SSMS.

[b] $DS = \frac{\text{measured elemental concentration}}{\text{Land DMEG}}$. Elements with DS > 1.0 are circled.

[c] day 1 Coal Feed data not available.

TABLE 28. SUMMARY AND COMPARISON OF TRACE ELEMENTS EXCEEDING LAND DMEG IN B&W/ALLIANCE BULK SOLID SAMPLES

	Waste streams				Feed streams		
	Cyclone catch		Spent bed material		Coal	Sorbent	
Element	BW1-1-03-CP	BW1-2-03-CP	BW1-1-04-CB	BW1-2-04-CB	BW1-2-05-CF[a]	BW1-1-06-LF	BW1-2-06-LF
Silicon	-	-	-	-	Health	-	-
Aluminum	-	Both[b]	Ecology	Ecology	Both	Ecology	Ecology
Phosphorus	Ecology	Ecology	Ecology	Ecology	Ecology	Ecology	Ecology
Calcium	Both	Both	Both	Both	-	Both	Both
Titanium	Ecology	Ecology	Ecology	Ecology	Ecology	-	Ecology
Vandium	Ecology	Ecology	Ecology	Ecology	-	-	-
Chromium	Both	-	-	-	-	-	-
Manganese	Both	Both	Both	Both	-	Both	Both
Iron	Both	Both	Both	Both	Both	Both	Both
Nickel	Both	Ecology	Ecology	Ecology	Ecology	Ecology	Ecology
Copper	Ecology	Ecology	-	-	-	-	-
Zinc	-	Ecology	-	-	-	-	-
Arsenic	Ecology	Ecology	Ecology	Both	-	-	-
Selenium	-	Both	Both	Both	-	Both	Both
Lead	Ecology	Ecology	-	-	-	-	-
Barium	Ecology	-	-	-	-	-	-

[a]Only data from Day 2 samples were available.

[b]Health indicates element exceeds health land DMEG.
Ecology indicates element exceeds health land DMEG.
Both indicates element exceeds both land DMEGs.

TABLE 29. SAM/1A INORGANIC TRACE ELEMENT ANALYSIS OF LABORATORY-GENERATED DISTILLED-WATER LEACHATES OF B&W/ALLIANCE BULK SOLID STREAM SAMPLES

Element (SSMS data)	Emission goal (DMEG) (µg/ℓ) Health	Ecology	Calculated Discharge Severities (DS) for Trace Elements in Leachates[a] Combustor cyclone solids (BW1-1-03-CP) Health	Ecology	(BW1-2-03-CP) Health	Ecology	Spent combustion bed material (BW1-1-04-CB) Health	Ecology	(BW1-2-04-CB) Health	Ecology
Lithium	330	380	0.02	0.02	0.08	0.07	<0.01	<0.01	<0.01	<0.01
Beryllium	30	55	<0.03	<0.02	<0.03	<0.02	<0.03	<0.02	<0.03	<0.02
Boron	47,000	25,000	0.01	0.02	0.01	0.02	<0.01	<0.01	<0.01	<0.01
Fluorine	38,000	-[b]	0.02	-	0.02	-	<0.01	-	<0.01	-
Sodium	800,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Magnesium	90,000	87,000	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Aluminum	80,000	1,000	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silicon	150,000	-	0.01	-	<0.01	-	<0.01	-	0.01	-
Phosphorus	15,000	0.5	<0.01	(10)	<0.01	(10)	<0.01	(6)	0	0
Sulfur	-	-	-	-	-	-	-	-	-	-
Chlorine	1,300,000	-	0.04	-	0.04	-	<0.01	-	<0.01	-
Potassium	-	-	-	-	-	-	-	-	-	-
Calcium	240,000	16,000	(2.5)	(38)	(2.5)	(38)	(2.5)	(38)	(2.5)	(38)
Scandium	800,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Titanium	90,000	820	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	250	100	<0.01	0.01	<0.01	<0.01	0	0	0	0
Iron	1,500	250	<0.01	0.01	0.02	0.09	<0.01	0.02	<0.01	0.02
Cobalt	750	250	<0.01	<0.01	<0.01	<0.01	0.03	0.09	<0.01	<0.01
Gallium	74,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Germanium	8,400	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Bromine	-	-	-	-	-	-	-	-	-	-
Rubidium	1,800,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Strontium	46,000	-	0.19	-	0.02	-	0.39	-	0.39	-
Yttrium	15,000	-	0	-	0	-	<0.01	-	<0.01	-
Zirconium	75,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Niobium	330,000	-	0	-	0	-	<0.01	-	<0.01	-
Molybdenum	75,000	7,000	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ruthenium	-	-	-	-	-	-	-	-	-	-
Rhodium	15	-	<0.07	-	<0.07	-	<0.07	-	<0.07	-
Palladium	-	-	-	-	-	-	-	-	-	-
Tin	-	-	-	-	-	-	-	-	-	-
Antimony	7,500	200	<0.01	0.03	<0.01	0.05	<0.01	<0.01	<0.01	<0.01
Tellurium	1,500	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Iodine	-	-	-	-	-	-	-	-	-	-
Cesium	1,200,000	-	0	-	0	-	<0.01	-	<0.01	-
Barium	5,000	2,500	0.03	0.06	0.06	0.12	0.22	0.44	0.11	0.23
Lanthanum	1,700,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Cerium	550,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Praseodymium	770,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Neodymium	-	-	-	-	-	-	-	-	-	-
Samarium	790,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Europium	-	-	-	-	-	-	-	-	-	-
Gadolinium	-	-	-	-	-	-	-	-	-	-
Terbium	-	-	-	-	-	-	-	-	-	-
Dysprosium	230,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Holmium	-	-	-	-	-	-	-	-	-	-
Erbium	-	-	-	-	-	-	-	-	-	-
Thulium	-	-	-	-	-	-	-	-	-	-
Ytterbium	15,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Lutetium	-	-	-	-	-	-	-	-	-	-
Haffnium	75,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Tungsten	15,000	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Rhenium	-	-	-	-	-	-	-	-	-	-
Osmium	-	-	-	-	-	-	-	-	-	-
Iridium	30	-	<0.03	-	<0.03	-	<0.03	-	<0.03	-
Gold	-	-	-	-	-	-	-	-	-	-
Thallium	1,500	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Bismuth	6,100	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Thorium	6,300	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-
Uranium	60,000	500	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	-
(AA Data)										
Arsenic	250	50	0.18	0.88	0.14	0.52	0.10	0.72	0.12	0.60
Cadmium	50	1	<0.01	0.29	<0.01	<0.10	<0.01	0.21	<0.01	<0.10
Chromium	250	250	0.02	0.02	0.08	0.08	0.03	0.03	0.08	0.08
Copper	5,000	50	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lead	250	50	<0.01	<0.02	<0.03	<0.02	<0.01	<0.02	<0.01	<0.02
Mercury	10	250	<0.10	<0.01	<0.10	<0.01	<0.10	<0.01	<0.10	<0.01
Nickel	230	10	(1.1)	(25)	(2.0)	(47)	0.40	(9.2)	(1.5)	(35)
Selenium	50	25	(1.3)	(2.6)	0.42	0.84	(1.4)	(2.8)	(1.6)	(3.3)
Vanadium	2,500	150	0.16	(2.7)	0.10	(1.6)	<0.01	0.67	0.02	0.33
Zinc	25,000	100	<0.01	<0.10	<0.01	<0.10	<0.01	<0.10	<0.01	<0.10

[a] Discharge Severity is defined as $\frac{\text{Measured elemental concentration}}{\text{Water DMEG}}$. Elements where DS ≥ 1.0 are circled.

[b] - = no DMEG has been adopted.

TABLE 30. COMPARISON OF TRACE ELEMENT CONCENTRATIONS IN B&W/ALLIANCE LEACHATES AND EPA OFFICE OF SOLID WASTE CRITERIA IDENTIFYING HAZARDOUS SOLID WASTES

	Cyclone catch (µg/l)		Spent bed material (µg/l)		
Element	BW1-1-03-CP	BW1-2-03-CP	BW1-1-04-CB	BW1-2-04-CB	OSW limits (µg/l)[a]
Arsenic	44[b]	36	26	30	5000
Cadmium	0.3	0.2	<0.1	<0.1	1000
Chromium	6.0	7.5	19	20	5000
Lead	<1.0	1.6	<1.0	<1.0	5000
Mercury	<1.0	<1.0	<1.0	<1.0	200
Selenium	66	41	21	41	1000

[a]See Federal Register, Volume 45, Number 98, Book 2, Page 3311, May 19, 1980.

TABLE 31. COMPARISON BETWEEN LEVELS OF ANION IN B&W/ALLIANCE LEACHATE AND DRINKING WATER REGULATIONS

	Maximum permissible concentration x 100 (mg/ℓ)[a]	Cyclone catch (µg/l)		Spent bed material (µg/l)	
Anion		BW1-1-03-CP	BW1-2-03-CP	BW1-1-04-CB	BW1-2-04-CB
F^-	1400-2400	3	2	1	2
Cl^-	25000	150	68	2	35
NO_3^- (as N)	1000	ND[b]	ND	ND	ND
SO_4^-	25000	2000	1800	710	1600

[a]Fluoride and nitrate limits are set under EPA National Interim Primary Drinking Water Regulations (40 CFR 141_); chloride and sulfate under EPA National Secondary Drinking Water Regulations (40 CFR 143).

[b]ND = Not detectable; detection limit was 0.1 mg/ℓ.

included in OSW regulations. Data in Table 31 show levels of these anions well below drinking water limits when the dilution factor is incorporated.

ORGANIC ANALYTIC RESULTS

As previously discussed, organic species of potential concern present in B&W/Alliance emission streams are assumed to be limited to the combustor flue gas streams. Organic content of the solid waste streams (cyclone catch and spent bed material) was so low, 1.6 µg/g and 7.6 µg/g, respectively, that no organic compound of potential concern could be present, even if the entire organic content were assumed to represent one toxic species. Therefore, interpretation of organic data was limited to flue gas stream component samples.

Table 32 lists organic compounds with the lowest air DMEGs for each designated Level 1 fraction based on those reported in Harris, et al. This compilation assumes that only those species for which DMEG values have been adopted are of potential concern. Table 33 summarizes organic analytic results for B&W/Alliance combustor flue gas samples. As discussed, candidate organic compounds of potential concern were determined by assuming that the entire organic weight content of the sample fraction represented one compound; all species with an air DMEG lower than that value were listed as being potentially present.

Rather than speculate as to the identity of organic species contained on/in flue gas particulate matter based on the limited analytic data available, such interpretations were based on bioassay results and data from HPLC/ fluorescence screening of appropriate samples.

BIOASSAY RESULTS

Table 34 presents a summary of Level 1 test data from bioassay of five effluent stream samples from the B&W/Alliance AFBC. Included are results of testing three SASS train components from combustor flue gas (BW1-1-01) and two bulk solids, cyclone catch (BW1-1-03) and spent combustion bed material (BW1-1-04). Results are presented as postive/negative for mutagenicity in S. typhimurium, for the Ames test and as the appropriate toxicologic parameter (LC_{50}, EC_{50}, etc.) for the remaining tests. These data have been assessed qualitatively using the currently recommended Level 1 criteria outlined in Table 22.

Health Effects Tests

Ames Test--

Of the five stream samples tested for mutagenicity, only combustor flue gas XAD extract (BW1-1-01-XM) had positive response. Data listed in Table 35 reveal mutagenic activity for this sample in frameshift tester strains TA 1537, TA 1538 and TA 98. Lowest recorded concentration (dose) which elicited a positive response (LRPC) was 5 µl. Gravimetric data reveal this volume contains approximately 12 µg CH_2Cl_2-extractable material. Relative

TABLE 32. ORGANIC COMPOUNDS WITH THE LOWEST AIR DMEG WITHIN DESIGNATED LEVEL 1 FRACTIONS

Level 1 Fractions	Organic Compounds or Classes	Air Discharge Multimedia Environmental Goals (μg/m³) Health-based	Ecology-based	Comments
Gaseous (GC)				
GC1	Acetylene	2.7 x 10^6	--	
	Methane	3.3 x 10^6	6.5 x 10^6	
	Ethylene	5.7 x 10^6	1.0	
GC2	Bromobutanes	5.6 x 10^4	--	
	Propyne	1.7 x 10^6	--	
	Propylene	8.6 x 10^6	1.8 x 10^5	
GC3	Diazomethane	400	--	Diazomethane is unstable; it is decomposed by heat, shock, and oxidizing agents. Therefore, the likelihood that it would be present in FBC emission streams is negligible. The value for formaldehyde is used.
	Formaldehyde	1200	--	
	Vinyl chloride	2600	--	
GC4	Methyl bromide	9.6 x 10^4	--	
GC5	Acrolein	250	--	
	Ethyleneimine	330	--	
	Methyl iodide	850	--	
GC6	N,N´-Dimethylhydrazine	32	--	N,N´-Dimethylhydrazine is unstable. This substance is a rocket fuel and its relevance to combustion processes is negligible. The value for benzene is used.
	Benzene	3000	--	
	Carbon tetrachloride	1.3 x 10^4	--	
GC7	No Information	X	X	
Volatile (TCO)				
LC1	Heptanes, octanes	3.5 x 10^5	--	
LC2	Hexachlorocyclopentadiene	110	--	
	Isopropyl benzene		1200	
LC3	PCBs	1	--	
LC4	1,1´-Dichloromethylether	5	--	
LC5	N-Nitrosodimethylamine	1.2	--	
LC6	1,4-Diaminobenzene	100	--	
LC7	Dimethyl sulfoxide	810	--	
Non-volatile (GRAV)				
LC1	No Information	X	X	
LC2	Hexachlorocyclohexane	500	--	
LC3	Benzo(a)pyrene	0.02	--	
LC4	2-chloroethyl ethyl ether	1.1 x 10^4	--	
LC5	3,4-Dinitrotoluene	1500	--	
LC6	Dibenzo(c,g)carbazole	100	--	
LC7	2,4,6-Trinitrophenol	100	--	
	3,3´-Dichlorobenzidine	100	--	

Note: -- = no goals have been set.

( ) = lowest discharge goal for the respective fraction is cited.

TABLE 33. COMBUSTOR FLUE GAS ORGANIC ANALYTIC RESULTS[a]

Level 1 Sample Fraction Designation	Measured Emissions ($\mu g/m^3$)	Maximum Discharge Severity[b]	Organic Compounds of Potential Concern
Gaseous			
GC1	392	0.0001 (392 ecological)	one - ethylene (ecological-based)
GC2	<123	<0.002	none
GC3	5388	4.5[c]	two - formaldehyde, vinyl chloride
GC4	22260	0.37	none
GC5	<294	1.18	one - acrolein
GC6	<351	0.12[d]	none
GC7	<408	No data available	--
Volatile (TCO)			
LC1	0.8	2.3×10^{-6}	none
LC2	0.9	0.008	none
LC3	1.8	1.8	one - PCBs
LC4	not detectable	--	none
LC5	1.2	1.0	one - N-nitroso dimethylamine
LC6	14.5	0.145	none
LC7	4.4	0.005	none
Non-volatile (GRAV)			
LC1	59.7	No data available	--
LC2	1.4	0.003	none
LC3	6.7	335	three, B(a)P, 1,2:5,6-dibenzanthracene, 3-methyl cholanthrene
LC4	10.4	0.0009	none
LC5	17.2	0.01	none
LC6	110.8	1.1	one - dibenzo(c,g)carbazole
LC7	144.7	1.4	two - 2,4,6-trinitrophenol, 3,3'-dichlorobenzidine
Particulate			
SASS Coarse (>3μm)	no data	Insufficient information to assign probable compound types.	
SASS Fine (<3μm)	30[e]		

[a]Results are reported for Day 2 samples (BW 1-2-01) only. Seventy percent of the Day 1 XAD extract was required for bioassay so LC fractionation was unable to be performed.

[b]Maximum DS based on air, health DMEG (except as noted) using the organic compounds with the most stringent DMEG for each fraction as listed in Table 32.

[c]Maximum DS would be 13.4 if diazomethane were considered. See comment in Table 32.

[d]Maximum DS would be 11.0 if N,N[1] - dimethylhydrazine were considered. See comment in Table 32.

[e]Total TCO + GRAV

TABLE 34 . RESULTS OF BIOLOGICAL TESTING OF B&W/ALLIANCE EFFLUENT STREAM SAMPLES

Sample identification	Health effects testing			Ecological effects testing		
	Ames (+/-)[a]	RAM (LC_{50})[b]	CHO (LC_{50})	Fish (LC_{50})[e]	Daphnia (LC_{50})	Algae (LC_{50})
SASS fine particles (<3μm) (BW 1-1-01-FC)	–	60 (MOD)[d]	NT	NT	NT	NT
SASS coarse particles (>3μm) (BW 1-1-01-CC)	–	785 (LOW)[d]	NT	NT	NT	NT
XAD extract (BW 1-1-01-XM)	+	NT	1.2(μl/ml) (HIGH)[d]	NT	NT	NT
Cyclone catch[f] (BW 1-1-03-CP)	–	435 (LOW)[d]	142 (LOW)[d]	12.3 (HIGH)[d]	10.7 (HIGH)[d]	8.7 (HIGH)[d]
Spent bed material[f] (BW 1-1-04-CB)	–	295 (LOW)[d]	358 (LOW)[d]	13.5 (HIGH)[d]	12.3 (HIGH)[d]	7.9 (HIGH)[d]

[a] +/- = positive or negative mutagenic response according to the criteria presented in Section 5.

[b] LC_{50} is reported as μg/ml except where indicated.

[c] NT = sample not tested in the indicated assay system.

[d] LOW = low toxicity; MOD = moderate toxicity; HIGH = high toxicity; ND = no detectable toxicity based on those criteria presented in Table 22.

[e] LC_{50} for fish tests is 96 hour; for Daphinia 48 hour.

[f] Leachates of these materials were tested in ecological effects tests.

TABLE 35. MUTAGENICITY OF ALLIANCE XAD RESIN EXTRACT (BW1-1-01-XM) (REVERTANTS PER PLATE IN INDICATED STRAINS)

Sample Concentration (µl/plate)	TA-1535				TA-1537				TA-1538				TA-98				TA-100			
	-		+		-		+		-		+		-		+		-		+	
	Raw Counts	Average	Raw Counts	Average	Raw Counts	Average	Raw Counts	Average	Raw Counts	Average	Raw Counts	Average	Raw Counts	Average	Raw Counts	Average	Raw Counts	Average	Raw Counts	Average
0	17 19	18	21 17	19	5 7	6	15 13	14	21 20	21	33 43	38	28 25	27	39 34	37	163 156	160	159 169	164
1.0	14 16	15	28 20	24	5 6	6	16 15	16	22 27	25	35 35	35	31 48	40	32 39	36	163 167	165	144 146	145
5.0	21 16	19	25 20	23	18 24	21 (15)	21 19	20 (6)	58 46	52 (31)	58 65	62 (24)	114 134	124 (97)	32 36	34	179 160	170	164 163	164
10.0	24 14	19	25 25	25	38 47	43 (37)	32 32	32 (18)	92 90	91 (70)	88 72	80 (42)	172 142	157 (130)	54 63	59 (22)	180 206	193	156 147	152
25.0	6 BR BR 9	8	25 24	25	96 73	85 (79)	41 61	51 (37)	161 188	175 (154)	181 175	178 (240)	272 279	276 (249)	110 113	112 (75)	263 272	268	175 154	165
50.0	3 BSR BSR 6	5	29 27	28	88 BSR BSR 109	99 (93)	96 98	97 (83)	285 bsr BSR 223	254 (233)	233 227	230 (192)	652 726	689 (662)	313 244	279 (242)	329 329	329	209 207	208
Positive Controls	SA-1 316 413	365	2AA-1 304 310	307	QH-200 1521 2919	2220	2AA-1 147 142	145	2NF-5 1423 1641	1532	2AA-1 1429 1338	1384	2NF-5 1289 1386	1338	2AA-1 2584 2554	2569	SA-10 2331 2402	2357	2AA-1 1845 2311	2078
Slope						1.657		1.669		4.387		3.824		12.657		5.620				
Correlation						0.924		0.997		0.984		0.966		0.984		0.989				

BR = Background reduced.
BSR = Background substantially reduced.
( ) = Data in parentheses represent an average value with background subtracted.

mutagenic activity of this sample, calculated using the number of revertants at the LRPC for the most active strain (TA 98), is 8 revertants/µg organics at the LRPC. This value is quite similar to that calculated for XAD extract of combustor flue gas at the Exxon Miniplant PFBC[15,16] and is well within the ranges reported for mutagenic activity in S. Typhimurium of samples obtained at other FBC facilities,[17] from other combustion or energy processes,[18-20] as well as from sampling of ambient air.[21-26]

Ames test data also reveal higher specific mutagenic activity in the absence of S-9 microsomal mix. These results are illustrated in Figure 13 for the most active strain (TA-98). Addition of the activation system generally reduced mutagenic response, similar to results observed from testing of Exxon PFBC samples.[15,16] These data indicate that polynuclear aromatic hydrocarbons (PNAs) cannot be the sole mutagenic species responsible for the observed activity.[27]

RAM Cytotoxicity

Of the four samples assayed, sample BW1-1-01-FC, the SASS fine particles (<3µm) from the combustor flue gas stream, elicited the highest toxic response in RAM cells based on viability index. The coarse particulate (>3µm) sample exhibited a relatively lower toxicity. Several investigators have demonstrated a direct relationship between decreasing particle size and increasing cytotoxic response.[28,29] This is corroborated by these data. EC_{50} values were calculated based on viability and ATP concentration. Results are summarized in Table 36. Relative ATP concentration may be seen to follow in the pattern of decreased cell viability. This is illustrated graphically for the fine particulate sample in Figure 14.

TABLE 36. EC_{50} BASED ON VIABILITY AND ATP CONCENTRATION CALCULATED FOR B&W/ALLIANCE SAMPLES TESTED IN THE RAM ASSAY

Sample	Viability index	ATP concentration
Fine particulates, BW1-1-01-FC	360 µg/plate (60 µg/ml)	60 µg/plate (10 µg/ml)
Coarse particulates, BW1-1-01-CC	4710 µg/plate (785 µg/ml)	5040 µg/plate (840 µg/ml)
Cyclone catch, BW1-1-03-CP	2610 µg/plate (435 µg/ml)	1050 µg/plate (175 µg/ml)
Bed reject, BW1-2-04-CB	2150 µg/plate (358 µg/ml)	960 µg/plate (160 µg/ml)

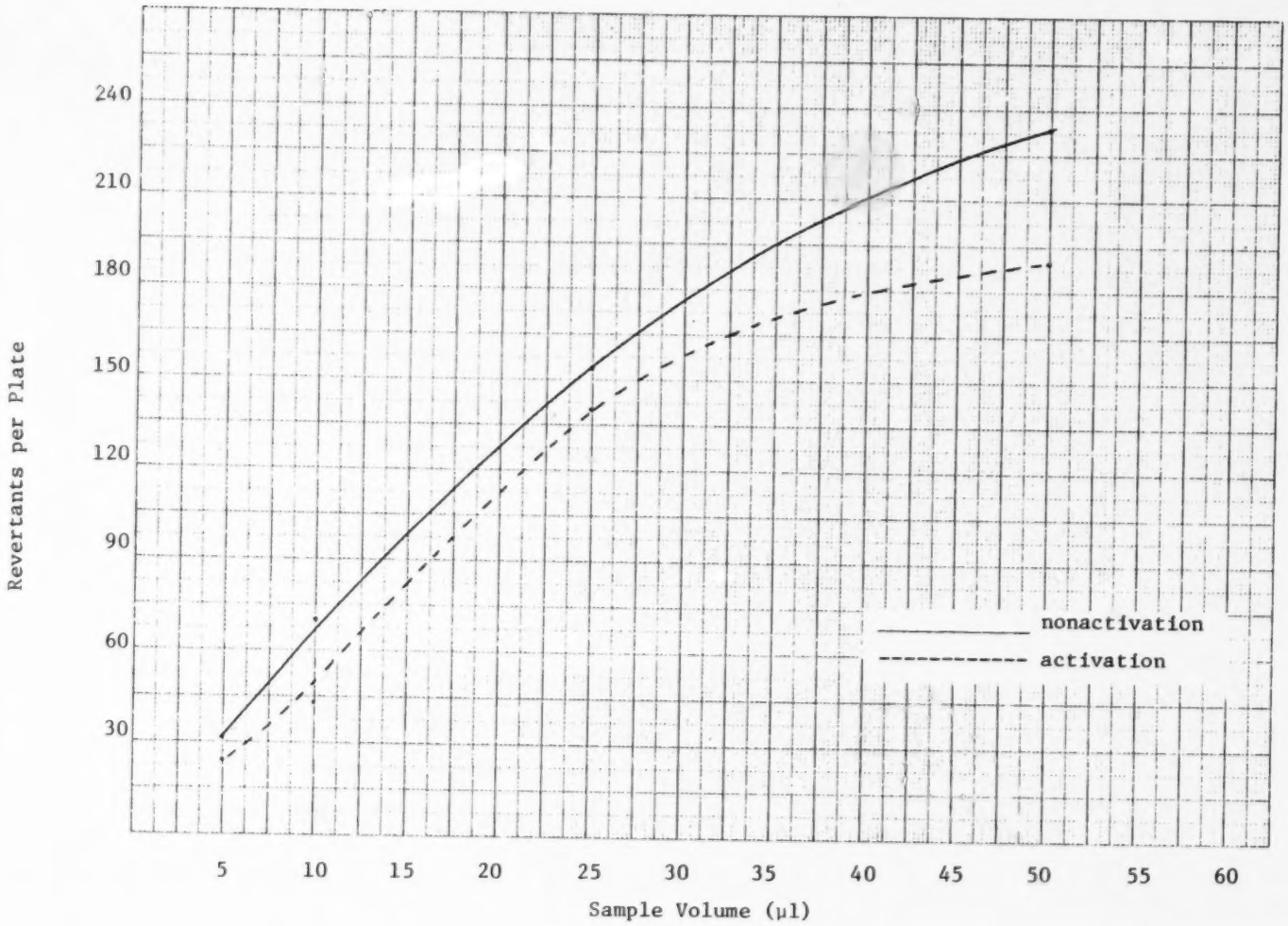

Figure 13. XAD resin extract (BW-1-01-XM) response in strain TA-98.

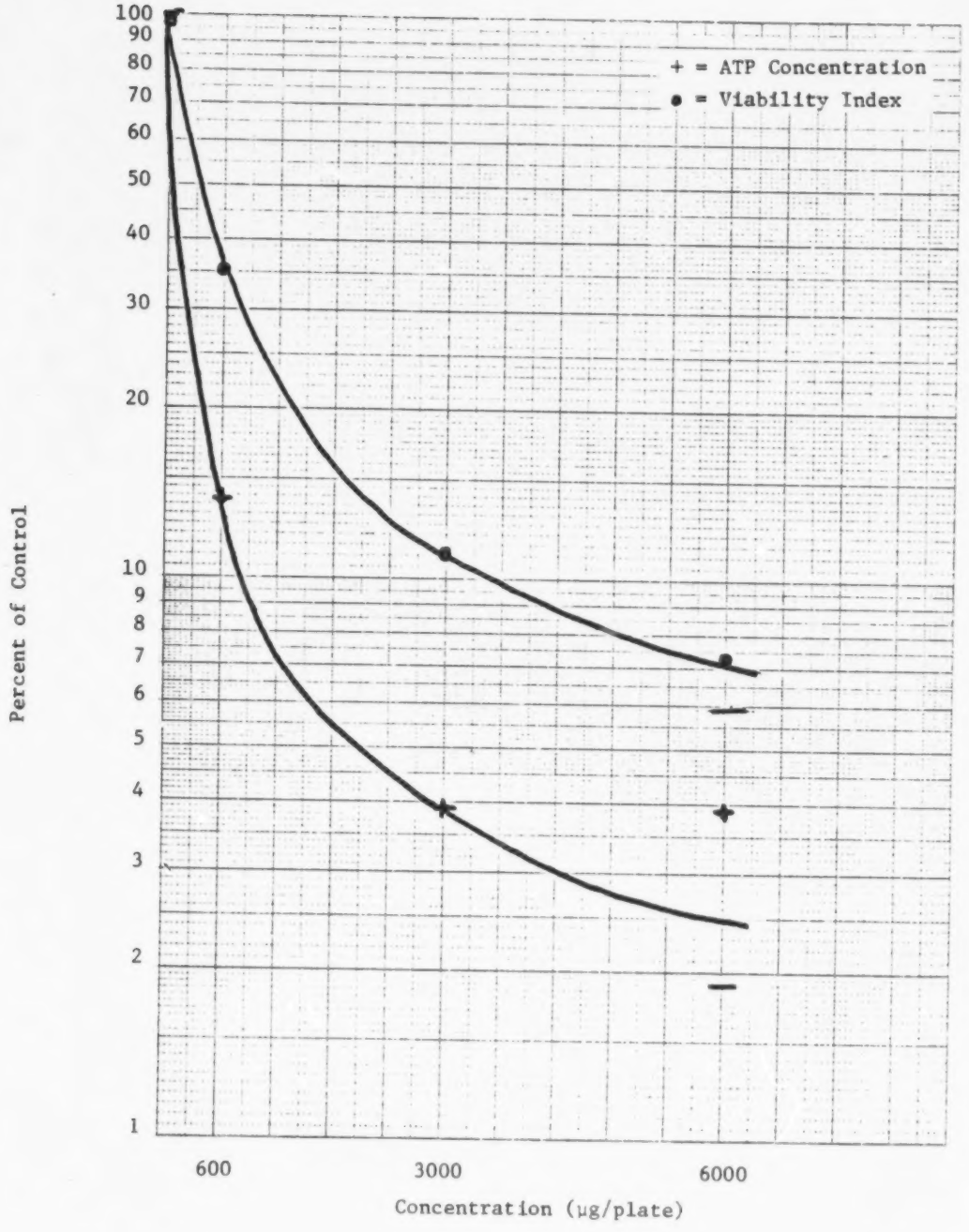

Figure 14. Response of fine particulate sample BW1-1-01-FC in RAM assay.

CHO Cytotoxicity--

As shown in Table 34 three B&W/Alliance samples were assayed using this test system. As indicated, combustor flue gas XAD-extract was the most toxic of the samples tested. This sample caused of 50 percent reduction in plating efficiency at a concentration of only 1.2 µl/ml. This response corroborates the biological activity observed for this sample in the Ames Test.

Ecological Effects Tests

Table 37 summarizes results of testing B&W/Alliance leachate samples in the Level 1 ecological effects test matrix.

Fish Test--

Data indicated both the cyclone catch and bed reject samples were highly toxic (less than 20 percent; see Table 34) to fathead minnows at concentrations of 12.3 percent and 13.5 percent, respectively.

Daphnia Test--

LC_{50} values for both samples were similar to those obtained in the fish bioassay tests. The 48-hour LC_{50} values for the bed reject and cyclone samples were 12.3 percent and 10.7 percent, respectively.

Algal Growth Test--

Using growth inhibition as the effect criteria, an EC_{50} value has been calculated for both samples. Normally this EC_{50} is calculated on the basis of algal growth rates from days 0-4. However, in the case of the cyclone catch sample, this was not possible. Sample concentrations of 5 and 10 percent produced a drastic inhibition in cell growth between days 0-2. Recovery, however, was also rapid and the rate of growth equalled or surpassed that of the controls after day 2. For this reason, the EC_{50} for the cyclone catch was calculated on the basis of growth rates from days 0-2. The results of this assay indicated that the acute toxicities of both the cyclone catch and the bed reject samples to the test alga were very high (EC_{50} = 1.3 percent and 7.9 percent, respectively, Table 37). The variability among replicates in the assay of the cyclone catch sample was somewhat higher than usual. Because of this, and because the EC_{50} was calculated on the basis of days 0-2 growth rates, the EC_{50} value was confirmed by additional testing. The first four days of the algal test was, therefore, re-run on the cyclone catch sample. The EC_{50} value, based on growth rates from days 0-4, was calculated to be 8.7 percent. This value, although higher than the original EC_{50} value, is within the range of high toxicity.

In the case of the bed reject sample, the maximum standing crop at the end of the test period was not significantly different from that of the control at any of the test concentrations. Exposure to both 5 percent and 10 percent cyclone catch effluent resulted in a maximum standing crop which was significantly less than that of the control value.

TABLE 37. LC_{50} AND ED_{50} VALUES OF ALLIANCE FBC LEACHATES EXPRESSED AS PERCENT CONCENTRATION (95 PERCENT CONFIDENCE INTERVAL)[a]

Leachate	Time Of Observations (hrs)	Fathead Minnow LC_{50}	*Daphnia* LC	Algal EC_{50}[b]
Cyclone Catch	24	12.7 (11.4 - 14.1)	12.3 (11.0 - 13.6)	1.3 (log extrapolation)
(BW 1-1-03-CP)	48	12.3 (11.0 - 13.6)	10.7 (9.5 - 11.8)	--
	96	12.3 (11.0 - 13.6)	--	--
Bed Reject	24	13.7 (12.5 - 15.1)	12.25 (11.0 - 13.6)	--
(BW 1-1-04-CB)	48	13.7 (12.5 - 15.1)	12.25 (11.0 - 13.6)	--
	96	13.5 (12.2 - 14.9)	--	7.85

(a) In cases where an LC_{50} could not be derived from probit analysis, it was calculated by the moving average-angle method (Harris, 1959).

(b) EC_{50} for Cyclone Catch was calculated from growth rate days 0-2, rather than the usual 0-4. See text for discussion.

SECTION 6

LEVEL 2 CHEMICAL INVESTIGATION OF B&W/ALLIANCE STREAM SAMPLES

Limited Level 2 chemical analysis was performed on selected B&W/Alliance samples. Our initial Level 2 analysis involved screening of selected samples using High Performance Liquid Chromatography (HPLC) with fluorescence detection. This procedure provides compound-specific data in a cost-effective manner and is especially useful for detection of Polynuclear Aromatic Hydrocarbons (PNAs). Compounds detected, detection limits, instrumental operating conditions and the analytical procedure have been described in Section 4.

B&W/Alliance stream samples analyzed by HPLC/Fluorescence included three SASS train component samples of the Day 1 combustor flue gas stream and cyclone hopper ash. Samples are listed below.

- SASS coarse (greater than 3 μm) particles (BW1-1-01-CC)
- SASS fine (less than 3 μm) (BW1-1-01-FC)
- SASS organic module (XAD-2 resin) (BW1-1-01-XM)
- Cyclone hopper ash (BW1-1-03-CP)

All samples were methylene chloride-extracted. Appropriate blanks were also run (XAD Blank and Soxhlet blank), and data were blank-corrected.

Flue gas stream component samples were selected for analysis based on positive response in the Ames mutagenicity assay and the two cytotoxicity tests. In addition, analysis of Level 1 organic data indicated the possibility that PNA species could be present in flue gas samples. Cyclone hopper ash was also run because of sample availability.

Results of HPLC/Fluoresence analysis are summarized in Table 38. Three PNAs potentially exceed their respective emission goals in SASS fine particles, while B(a)P/B(e)P exceeds its air DMEG in XAD-extract. It must be noted that B(a)P/B(e)P and 7,12 DMBA/1,2,5,6-Dibenzanthracene exceed their goals if only the goal of the more hazardous (underlined) of the co-elutors is used for comparison. Discharge goals for B(e)P and 1,2,3,4-Dibenzanthracene are four and five orders of magnitude higher than the more stringent goal used. Further investigation of these components would only be justified on a worst-case

basis, that is, if the more hazardous of the two compounds among those pairs which co-elute represented most or all of the concentration listed. This is extremely unlikely.

Further analysis of particulate samples for 1,2,5,6-Dibenzanthracene might be warranted.

TABLE 38. HPLC/FLUORESCENCE DATA FROM SCREENING OF B&W/ALLIANCE SAMPLES FOR POLYNUCLEAR AROMATIC HYDROCARBONS

Suspected component(s)	Health-based DMEGs		CH_2Cl_2-extracted SASS coarse (>3 μm) particles (μg/m³/μg/g)	CH_2Cl_2-extracted SASS fine (<3 μm) particles (μg/m³/μg/g)	CH_2Cl_2-extracted XAD-2 resin (μg/m)	CH_2Cl_2-extracted cyclone hopper ash (μg/g)
	Air (μg/m³)	Land (μg/g)				
Naphthalene	50,000	150,000	<253/<0.70	16.6/9	<2.6	<0.15
Anthracene	56,000	170,000	<0.4/<0.012	<249/<0.073	<0.043	<0.0024
Fluoranthene/Pyrene[a]	90,000	28,000	<2.7/<0.074	<868/0.47	0.34	<0.016
2-Methylanthracene	-	-	<2.8/<0.078	<904/0.49	<0.29	<0.016
Benz(a)anthracene/ Triphenylene/chrysene	45	134	<0.03/<0.0009	<26/<0.014	<0.13	<0.00018
Benzo(k)fluoranthene	1,600	4,500	<0.003/<9 x 10^{-5}	<0.98/<0.0005	<0.0003	<0.000018
Benzo(a)pyrene/Benzo(e)pyrene	0.02	0.06	<0.01/<0.0003	<2.2/<0.0012	<0.024	<0.000062
7,12-Dimethylbenzanthracene/ 1,2,3,4-Dibenzoanthracene	0.26	0.78	<0.76/<0.021	<240/<0.24	<0.078	<0.0044
1,2,5,6-Dibenzanthracene	0.093	0.28	<0.02/<0.0006	<7/<0.0038	<0.0022	<0.00013
Indeno(1,2,3-cd)pyrene	1,630	4,800	<0.94/<0.026	<295/<0.16	0.34	<0.0054
Benzo(ghi)perylene	-	-	<0.036/<0.001	<16/0.0087	<0.0035	<0.00020
Anthanthrene	-	-	<1.2/<0.032	<369/<0.2	<0.12	<0.0067
Cornene	-	-	<0.007/<0.0002	<1.8/<0.001	<0.0016	<0.000032

[a]Where more than one species is listed, co-elution occurs under our experimental conditions. Where co-elution occurs, the more stringent emission goal is used for comparison and that species is underlined.

[b]- Indicates no DMEG has been adopted.

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APPENDIX A

SSMS DATA — B&W/ALLIANCE COMBUSTOR FLUE GAS STREAM SAMPLES

SITE F04: VOLUME SAMPLED=26.2MDSCM

Boiler-1, Alliance Coal

ELEMENT	10+3UM CYCLONE (MG)	PF+1UM CYCLONE (MG)	XAD RESIN (MG)	COMPOSITE SAMPLE (MG)	TOTAL SASS (MG)	EMISSION FOUND (MG/DSCM)	FUEL (PPM)	EMISSIONS POTENTIAL (MG/DSCM)
RU	< 0.96	< 0.11	< 0.050	< 0.046	< 1.2	< 0.044	< 0.030	< 0.0029
MO	0.85	0.20	0.069	1.3	2.4	0.091	1.0	0.099
NB	6.7	3.0	< 0.0058	0.0054	9.6	0.37	0.42	0.040
ZR	65.	29.	< 0.022	< 0.020	94.	3.6	13.	1.3
Y	15.	12.	< 0.0089	< 0.0083	25.	0.97	2.7	0.26
SR	130.	57.	< 0.18	0.0100	190.	7.1	53.	5.2
RB	39.	12.	< 0.0054	< 0.0025	51.	2.0	6.5	0.63
SM	41.	9.1	< 0.14	< 0.062	51.	1.9	0.28	0.027
SE	7.0	4.2	< 0.026	0.74	12.	0.45	2.0	0.19
AS	35.	21.	< 0.0100	0.0097	55.	2.1	12.	1.2
GE	3.0	1.3	< 0.018	< 0.017	4.3	0.16	0.67	0.065
GA	10.	4.9	< 0.0075	0.014	15.	0.57	1.7	0.16
ZN	52.	8.2	< 0.54	0.51	61.	2.3	11.	1.0
CU	30.	20.	< 0.48	0.055	50.	1.9	4.3	0.41
NI	31.	28.	< 0.48	30.	89.	3.4	4.5	0.44
CO	10.	4.6	< 0.0074	0.41	15.	0.59	1.1	0.11
FE	**	MC	< 1.9	120.	-	-	0.51 (%)	490.
MN	550.	19.	0.024	5.9	580.	14.	1.9	0.18
CR	15.	6.3	< 0.45	26.	46.	1.8	7.5	0.73
V	64.	14.	< 0.0065	0.18	79.	3.0	7.6	0.74
TI	**	950.	< 0.074	< 0.0034	**	79.	240.	23.
SC	8.4	3.7	< 0.0026	< 0.0024	12.	0.46	0.78	0.076
CA	MC	MC	< 13.	1.0	-	-	200.	20.
K	**	**	< 0.57	0.25	**	180.	770.	75.
CL	**	110.	< 4.1	< 0.016	**	83.	< 4.9	< 0.48
S	**	**	< 74.	**	**	**	0.59 (%)	580.
P	390.	86.	< 0.51	0.21	480.	18.	14.	1.3
SI	MC	MC	< 3.9	61.	-	-	0.82 (%)	790.
AL	**	MC	< 0.40	0.37	-	-	0.22 (%)	210.
MG	**	100.	25.	2.8	**	62.	84.	8.2
NA	**	450.	< 5.7	0.51	**	100.	79.	7.7
F	940.	75.	< 0.665	0.90	**	39.	9.7	0.94
B	480.	110.	< 0.092	1.4	580.	22.	7.4	0.72
BE	1.8	0.82	< 0.0008	< 0.0004	2.6	0.099	0.055	0.0054
LI	26.	4.1	< 0.0076	0.0005	30.	1.1	1.8	0.17

MC INDICATES A MAJOR COMPONENT OF THE SAMPLE.

- INDICATES THAT THE TOTAL AND EMISSION VALUES WERE NOT CALCULATED OWING TO THE PRESENCE OF AN MC CONCENTRATION.

** INDICATES A VALUE EXCEEDING ONE GRAM.

SITE F04: VOLUME SAMPLED=26.28DSCM

Run-1-01, Alliance Dual

ELEMENT	10*SUM CYCLONE (MG)	PP+10M CYCLONE (MG)	XAD RESIN (MG)	COMPOSITE SAMPLE (MG)	TOTAL SASS (MG)	EMISSION FOUND (MG/DSCM)	FUEL (PPM)	EMISSIONS POTENTIAL (MG/DSCM)
U	< 1.5	0.58	< 0.067	< 0.062	0.58 TO 1.4	0.022 TO 0.055	0.60	0.058
TH	< 1.8	1.5	< 0.090	< 0.090	1.5	0.058	1.7	0.17
BI	< 0.79	0.087	< 0.030	< 0.028	0.087 TO 0.85	0.0033 TO 0.032	0.036	0.0035
PB	15.	12.	0.12	< 0.058	25.	0.96	4.4	0.43
TL	< 0.95	1.0	< 0.037	< 0.035	1.0	0.038	0.40	0.039
AU	< 1.2	< 0.13	< 0.050	< 0.047	< 1.4	< 0.052	0.030	0.0029
IR	< 1.8	< 0.20	< 0.077	< 0.072	< 2.1	< 0.081	0.11	0.011
OS	< 1.9	< 0.21	< 0.085	< 0.078	< 2.3	< 0.088	< 0.050	< 0.0049
RE	< 1.2	< 0.14	< 0.053	< 0.049	< 1.5	< 0.056	< 0.032	< 0.0031
W	< 0.82	< 0.091	< 0.071	< 0.066	< 1.0	< 0.040	0.090	0.0088
HF	< 4.0	< 0.45	< 0.088	< 0.083	< 4.6	< 0.18	0.27	0.026
LU	< 1.0	< 0.11	< 0.021	< 0.019	< 1.1	< 0.044	0.012	0.0012
YB	< 0.73	0.12	< 0.030	< 0.028	0.12 TO 0.79	0.0045 TO 0.030	0.14	0.014
TM	< 0.43	0.047	< 0.018	< 0.017	0.047 TO 0.46	0.0018 TO 0.018	0.044	0.0043
ER	< 1.3	0.40	< 0.054	< 0.051	0.40 TO 1.4	0.015 TO 0.052	0.36	0.035
HO	< 0.21	0.045	< 0.018	< 0.017	0.045 TO 0.24	0.0017 TO 0.0091	0.080	0.0078
DY	1.6	0.18	< 0.031	< 0.029	1.8	0.068	0.22	0.021
TB	< 0.14	0.015	< 0.0084	< 0.0078	0.015 TO 0.16	0.0006 TO 0.0059	0.038	0.0037
GD	< 0.71	0.50	< 0.031	< 0.029	0.50	0.019	0.22	0.021
EU	< 0.50	0.085	< 0.014	< 0.013	0.085 TO 0.52	0.0032 TO 0.020	0.068	0.0066
SM	< 1.5	1.3	< 0.054	< 0.050	1.3	0.048	0.93	0.090
ND	4.6	3.8	< 0.067	< 0.063	8.5	0.32	5.4	0.52
PR	2.1	0.91	< 0.012	< 0.011	3.0	0.11	0.43	0.042
CE	11.	4.9	< 0.016	< 0.015	16.	0.61	6.8	0.66
LA	11.	5.0	< 0.017	< 0.016	16.	0.62	2.5	0.24
BA	210.	46.	< 2.9	< 0.022	260.	9.7	44.	4.3
CS	1.9	0.60	< 0.0028	< 0.0026	2.5	0.097	0.40	0.039
I	0.94	0.78	< 0.092	< 0.043	1.7	0.065	0.028	0.0027
TE	< 0.87	< 0.096	< 0.039	< 0.036	< 1.0	< 0.039	0.025	0.0024
SB	0.62	0.28	< 0.027	< 0.025	0.90	0.034	0.12	0.012
SN	1.5	0.33	< 0.076	< 0.29	1.8	0.069	0.51	0.050
CD	0.38	0.084	0.037	< 0.045	0.50	0.019	0.42	0.040
PD	< 1.2	< 0.13	< 0.039	< 0.036	< 1.4	< 0.053	0.028	0.0028

SITE F03: VOLUME SAMPLED=28.25DSCM

BCW1-2-01

ELEMENT	10+3UM CYCLONE (MG)	PF+1UM CYCLONE (MG)	XAD RESIN (MG)	COMPOSITE SAMPLE (MG)	TOTAL SASS (MG)	EMISSION FOUND (MG/DSCM)	FUEL (PPM)	EMISSIONS POTENTIAL (MG/DSCM)
RU	< 1.9	< 0.049	< 0.025	< 0.020	< 2.0	< 0.070	< 0.12	< 0.013
MO	< 1.2	0.23	0.064	5.5	5.6	0.20	1.1	0.12
NB	5.5	1.4	< 0.0029	0.33	5.2	0.18	0.42	0.045
ZR	39.	15.	0.044	< 0.0100	55.	1.9	0.3	0.07
Y	26.	5.5	< 0.0045	< 0.0045	32.	1.1	2.6	0.28
SR	250.	26.	0.26	< 0.0053	280.	9.8	27.	2.9
RB	18.	5.7	0.0027	< 0.0013	24.	0.85	6.5	0.70
BR	20.	4.2	0.19	< 0.052	25.	0.87	1.2	0.13
SE	9.0	1.9	0.013	1.5	12.	0.44	4.6	0.45
AS	32.	14.	< 0.0052	< 0.0049	46.	1.6	8.3	0.89
GE	< 0.78	2.4	< 0.0045	< 0.0045	2.4	0.086	1.6	0.17
SA	4.9	1.6	< 0.0038	0.011	6.5	0.23	2.2	0.23
ZN	18.	3.8	< 2.2	1.0	23.	0.81	10.	1.1
CU	21.	2.2	< 2.0	0.23	23.	0.82	9.1	0.98
NI	61.	6.4	< 0.48	31.	98.	3.5	2.0	0.22
CO	20.	1.1	0.014	0.88	22.	0.79	1.1	0.11
FE	**	**	2.4	120.	**	**	0.35	(2) 370.
MN	170.	5.9	0.071	6.0	190.	6.6	3.7	0.40
CR	50.	6.2	1.5	27.	84.	2.5	5.7	0.60
V	60.	6.5	< 0.013	0.089	67.	2.4	7.8	0.82
TI	**	320.	0.12	0.11	**	67.	240.	26.
SC	< 0.27	< 0.0071	0.020	< 0.0013	0.020 TO 0.28	0.0007 TO 0.0100	0.75	0.081
CA	MC	**	< 25.	0.44	-	-	280.	30.
K	**	100.	< 2.3	0.12	**	120.	0.15	(2) 170.
CL	**	12.	15.	0.49	**	50.	< 9.8	< 1.1
S	MC	**	110.	290.	-	-	2.4	(2) 2500.
P	380.	20.	0.55	0.21	400.	14.	55.	5.9
SI	**	580.	250.	1.7	**	820.	3.5	(2) 3500.
AL	**	**	< 1.8	0.58	**	590.	MC	-
MG	710.	37.	1.6	1.4	750.	26.	240.	26.
NA	120.	210.	< 5.4	1.2	330.	12.	< 6.8	< 0.73
F	920.	23.	0.090	0.11	940.	33.	19.	2.1
B	930.	29.	< 0.095	0.18	960.	34.	30.	3.2
BE	1.7	0.090	0.0008	< 0.0004	1.8	0.065	0.46	0.049
LI	25.	1.3	< 0.0038	< 0.0004	27.	0.94	3.5	0.38

MC INDICATES A MAJOR COMPONENT OF THE SAMPLE.

- INDICATES THAT THE TOTAL AND EMISSION VALUES WERE NOT CALCULATED OWING TO THE PRESENCE OF AN MC CONCENTRATION.

** INDICATES A VALUE EXCEEDING ONE GRAM.

SITE F03: VOLUME SAMPLED=28.23DSCM

BWI-2-01

ELEMENT	10+SUM CYCLONE (MG)	PP+1UM CYCLONE (MG)	XAD RESIN (MG)	COMPOSITE SAMPLE (MG)	TOTAL SASS (MG)	EMISSION FOUND (MG/DSCM)	FUEL (PPM)	EMISSIONS POTENTIAL (MG/DSCM)
U	< 2.0	0.50	< 0.034	< 0.032	0.50 TO 2.8	0.018 TO 0.093	0.84	0.069
TM	< 3.0	2.8	< 0.049	< 0.048	2.8	0.100	1.7	0.19
BI	< 1.5	0.16	0.015	< 0.014	0.18 TO 1.6	0.0062 TO 0.055	0.036	0.0059
RB	14.	5.4	0.47	< 0.030	20.	0.70	4.4	0.47
TL	< 1.9	0.86	< 0.019	< 0.018	0.86 TO 1.9	0.051 TO 0.087	0.43	0.046
AU	< 2.3	< 0.054	< 0.025	< 0.024	< 2.4	< 0.084	0.24	0.026
IR	< 3.5	< 0.090	< 0.059	< 0.057	< 5.7	< 0.13	< 0.18	< 0.020
OS	< 3.0	< 0.098	< 0.042	< 0.040	< 4.0	< 0.14	< 0.20	< 0.022
RE	< 2.4	< 0.062	< 0.027	< 0.025	< 2.5	< 0.089	< 0.13	< 0.014
N	< 1.8	< 0.042	< 0.036	< 0.034	< 1.7	< 0.061	< 0.17	< 0.018
HF	< 7.9	0.53	< 0.045	< 0.042	0.53 TO 8.0	0.019 TO 0.28	< 0.21	< 0.023
LU	< 2.0	0.051	< 0.0100	< 0.0099	0.051 TO 2.0	0.0018 TO 0.070	< 0.050	< 0.0053
YB	< 1.4	0.15	< 0.015	< 0.014	0.15 TO 1.5	0.0055 TO 0.052	0.072	0.0078
TM	< 0.85	0.043	< 0.0093	< 0.0088	0.043 TO 0.85	0.0015 TO 0.030	< 0.044	< 0.0048
ER	< 2.5	0.16	< 0.027	< 0.026	0.16 TO 2.5	0.0056 TO 0.089	0.26	0.028
HO	< 0.40	0.042	< 0.0089	< 0.0085	0.042 TO 0.42	0.0015 TO 0.015	0.043	0.0046
DY	1.4	0.61	< 0.016	< 0.015	1.7	0.061	0.63	0.067
TB	< 0.27	0.028	< 0.0042	< 0.0040	0.028 TO 0.28	0.0010 TO 0.0099	0.020	0.0022
GD	< 1.4	0.17	< 0.015	< 0.015	0.17 TO 1.4	0.0062 TO 0.050	0.12	0.013
EU	< 0.97	0.11	< 0.0076	< 0.0067	0.11 TO 0.99	0.0039 TO 0.035	0.15	0.016
SM	1.5	1.0	< 0.027	< 0.026	2.5	0.087	0.49	0.053
ND	4.7	3.6	< 0.034	< 0.032	8.3	0.29	8.0	0.86
PR	1.1	0.80	< 0.0060	< 0.0057	1.9	0.068	0.86	0.092
CE	22.	4.5	0.12	< 0.0077	26.	0.94	4.2	0.44
LA	22.	4.6	< 0.0087	< 0.0083	27.	0.94	2.5	0.27
BA	150.	20.	< 1.4	< 0.011	160.	5.6	21.	2.2
CS	1.9	0.39	< 0.0014	< 0.0013	2.3	0.081	0.40	0.043
I	1.8	0.56	0.13	< 0.022	2.5	0.082	0.078	0.0084
IE	< 1.7	< 0.044	< 0.020	< 0.019	< 1.8	< 0.063	< 0.093	< 0.0100
SN	< 1.2	0.24	< 0.014	< 0.013	0.24 TO 1.2	0.0084 TO 0.044	0.26	0.028
CD	< 1.4	0.28	< 0.29	0.14	0.42 TO 1.7	0.015 TO 0.062	1.2	0.13
PD	< 2.3	< 0.061	< 0.019	< 0.018	0.086 TO 0.43	0.0030 TO 0.015	0.43	0.046
					< 2.4	< 0.087	< 0.093	< 0.0100

SITE PUG: VOLUME SAMPLED=26.28DSCM

EW1-1-01, Alliance Dock

ELEMENT	10-SUM CYCLONE (MG)	PF-1UM CYCLONE (MG)	XAD RESIN (MG)	COMPOSITE SAMPLE (MG)	TOTAL SASS (MG)	EMISSION FOUND (MG/DSCM)	FUEL (PPM)	EMISSIONS POTENTIAL (MG/DSCM)
U	< 1.5	0.58	< 0.067	< 0.062	0.58 TO 1.4	0.022 TO 0.055	0.60	0.058
TH	< 1.8	1.5	< 0.090	< 0.080	1.5	0.058	1.7	0.17
BI	< 0.79	0.087	< 0.030	< 0.028	0.087 TO 0.85	0.0033 TO 0.032	0.036	0.0035
PB	13.	12.	0.12	< 0.058	25.	0.96	4.4	0.43
TL	< 0.95	1.0	< 0.037	< 0.035	1.0	0.038	0.40	0.039
AU	< 1.2	< 0.13	< 0.050	< 0.047	< 1.4	< 0.052	0.030	0.0029
IR	< 1.8	< 0.20	< 0.077	< 0.072	< 2.1	< 0.081	0.11	0.011
OS	< 1.9	< 0.21	< 0.083	< 0.078	< 2.3	< 0.088	< 0.050	< 0.0049
RE	< 1.2	< 0.14	< 0.053	< 0.049	< 1.5	< 0.056	< 0.032	< 0.0031
W	< 0.82	< 0.091	< 0.071	< 0.066	< 1.0	< 0.040	0.090	0.0088
HF	< 4.0	< 0.45	< 0.088	< 0.083	< 4.6	< 0.18	0.27	0.026
LU	< 1.0	< 0.11	< 0.021	< 0.019	< 1.1	< 0.044	0.012	0.0012
YB	< 0.73	0.12	< 0.030	< 0.028	0.12 TO 0.79	0.0045 TO 0.030	0.14	0.014
TM	< 0.43	0.047	< 0.018	< 0.017	0.047 TO 0.46	0.0018 TO 0.018	0.044	0.0043
ER	< 1.3	0.40	< 0.054	< 0.051	0.40 TO 1.4	0.015 TO 0.052	0.36	0.035
HO	< 0.21	0.045	< 0.018	< 0.017	0.045 TO 0.24	0.0017 TO 0.0091	0.080	0.0078
DY	1.6	0.18	< 0.031	< 0.029	1.8	0.068	0.22	0.021
TB	< 0.14	0.015	< 0.0084	< 0.0078	0.015 TO 0.16	0.0006 TO 0.0059	0.038	0.0037
GD	< 0.71	0.50	< 0.031	< 0.029	0.50	0.019	0.22	0.021
EU	< 0.50	0.085	< 0.014	< 0.013	0.085 TO 0.52	0.0032 TO 0.020	0.068	0.0066
SM	< 1.5	1.3	< 0.054	< 0.050	1.3	0.048	0.93	0.090
ND	4.6	5.8	< 0.067	< 0.063	8.5	0.32	5.4	0.52
PR	2.1	0.91	< 0.012	< 0.011	3.0	0.11	0.43	0.042
CE	11.	4.9	< 0.016	< 0.015	16.	0.61	6.8	0.66
LA	11.	5.0	< 0.017	< 0.016	16.	0.62	2.5	0.24
BA	210.	46.	< 2.9	< 0.022	260.	9.7	40.	4.5
CS	1.9	0.60	< 0.0028	< 0.0026	2.5	0.097	0.40	0.039
I	0.94	0.78	< 0.092	< 0.043	1.7	0.065	0.028	0.0027
TE	< 0.87	< 0.096	< 0.039	< 0.036	< 1.0	< 0.039	0.025	0.0024
SB	0.62	0.28	< 0.027	< 0.025	0.90	0.034	0.12	0.012
SN	1.5	0.33	< 0.076	< 0.29	1.8	0.069	0.51	0.050
CD	0.38	0.084	0.037	< 0.045	0.50	0.019	0.42	0.040
PD	< 1.2	< 0.13	< 0.039	< 0.036	< 1.4	< 0.053	0.028	0.0028

SITE POSS VOLUME SAMPLED=28.25DSCM

SW1-2-01

ELEMENT	10+SUM CYCLONE (MG)	PP+SUM CYCLONE (MG)	XAD RESIN (MG)	COMPOSITE SAMPLE (MG)	TOTAL SASS (MG)	EMISSION FOUND (MG/DSCM)	FUEL (PPM)	EMISSIONS POTENTIAL (MG/DSCM)
AU	< 1.9	< 0.049	< 0.025	< 0.024	< 2.0	< 0.070	< 0.12	< 0.015
AU	< 1.2	0.25	0.069	5.5	5.8	0.20	1.1	0.12
AB	5.5	1.4	< 0.0029	0.55	5.2	0.18	0.42	0.045
ZR	39.	15.	0.040	< 0.0100	55.	1.9	6.3	0.67	
Y	26.	5.5	< 0.0045	< 0.0045	32.	1.1	2.6	0.28
SM	250.	26.	0.20	< 0.0055	280.	9.8	27.	2.9
MO	18.	5.7	0.0027	< 0.0013	24.	0.85	6.5	0.70
GD	20.	4.2	0.19	< 0.052	25.	0.87	1.2	0.13
SE	9.0	1.9	0.013	1.5	12.	0.44	4.0	0.45
AS	32.	14.	< 0.0052	< 0.0049	46.	1.6	8.3	0.89
GE	< 0.78	2.4	< 0.0095	< 0.0089	2.8	0.086	1.6	0.17
GA	4.9	1.6	< 0.0038	0.011	6.5	0.23	2.2	0.25
ZN	18.	5.8	< 2.2	1.0	25.	0.81	10.	1.1
CU	21.	2.2	< 2.0	0.25	25.	0.82	9.1	0.98
VI	61.	6.4	< 0.48	31.	98.	3.5	2.0	0.22
CO	20.	1.1	0.014	0.88	22.	0.79	1.1	0.11
FE	**	**	2.9	120.	**	**	0.35	(I) 370.
MN	170.	8.9	0.071	6.0	190.	6.6	3.7	0.40
CR	30.	6.2	1.5	27.	64.	2.3	3.7	0.40
V	60.	8.5	< 0.013	0.089	67.	2.4	7.6	0.82
TI	**	320.	0.12	0.11	**	67.	240.	26.
SC	< 0.27	< 0.0071	0.020	< 0.0013	0.020 TO 0.28	0.0007 TO 0.0100	0.75	0.081
CA	MC	**	< 25.	0.44	-	-	280.	30.
K	**	160.	< 2.3	0.12	**	120.	0.15	(I) 170.
CL	**	12.	13.	0.49	**	36.	< 9.8	< 1.1
S	MC	**	110.	290.	-	-	2.4	(I) 2500.
P	380.	20.	0.55	0.21	400.	14.	55.	5.9
SI	**	580.	250.	1.7	**	820.	3.5	(I) 5800.
AL	**	**	< 1.8	0.38	**	590.	MC	-
MG	710.	37.	1.6	1.4	750.	26.	240.	26.
NA	120.	210.	< 5.4	1.2	330.	12.	< 6.8	< 0.75
F	920.	25.	0.090	0.11	940.	33.	19.	2.1
B	950.	24.	< 0.093	0.18	960.	34.	30.	3.2
BE	1.7	0.090	0.0008	< 0.0004	1.8	0.065	0.46	0.049
LI	25.	1.5	< 0.0038	< 0.0004	27.	0.94	3.5	0.38

MC INDICATES A MAJOR COMPONENT OF THE SAMPLE.

- INDICATES THAT THE TOTAL AND EMISSION VALUES WERE NOT CALCULATED OWING TO THE PRESENCE OF AN MC CONCENTRATION.

** INDICATES A VALUE EXCEEDING ONE GRAM.

SITE F03: VOLUME SAMPLED=28.25DSCM
B001-2-01

ELEMENT	10+3UM CYCLONE (MG)	PF+1UM CYCLONE (MG)	XAD RESIN (MG)	COMPOSITE SAMPLE (MG)	TOTAL SASS (MG)	EMISSION FOUND (MG/DSCM)	FUEL (PPM)	EMISSIONS POTENTIAL (MG/DSCM)
U	< 2.6	0.50	< 0.034	< 0.032	0.50 TO 2.6	0.018 TO 0.093	0.64	0.069
TH	< 3.6	2.6	< 0.049	< 0.046	2.6	0.100	1.7	0.19
BI	< 1.5	0.16	0.015	< 0.014	0.18 TO 1.6	0.0062 TO 0.055	0.036	0.0039
PB	14.	5.4	0.47	< 0.030	20.	0.70	4.4	0.47
TL	< 1.9	0.86	< 0.019	< 0.018	0.86 TO 1.9	0.031 TO 0.067	0.43	0.046
AU	< 2.3	< 0.059	< 0.025	< 0.024	< 2.4	< 0.084	0.24	0.026
IR	< 5.5	< 0.090	< 0.039	< 0.037	< 5.7	< 0.13	< 0.18	< 0.020
OS	< 3.8	< 0.098	< 0.042	< 0.040	< 4.0	< 0.14	< 0.20	< 0.022
RE	< 2.4	< 0.062	< 0.027	< 0.025	< 2.5	< 0.089	< 0.13	< 0.014
W	< 1.6	< 0.042	< 0.036	< 0.034	< 1.7	< 0.061	< 0.17	< 0.018
HF	< 7.9	0.53	< 0.045	< 0.042	0.53 TO 8.0	0.019 TO 0.28	< 0.21	< 0.023
LU	< 2.0	0.051	< 0.0100	< 0.0099	0.051 TO 2.0	0.0018 TO 0.070	< 0.050	< 0.0055
YB	< 1.4	0.15	< 0.015	< 0.014	0.15 TO 1.5	0.0055 TO 0.052	0.072	0.0078
TM	< 0.83	0.043	< 0.0093	< 0.0088	0.043 TO 0.85	0.0015 TO 0.030	< 0.044	< 0.0048
ER	< 2.5	0.16	< 0.027	< 0.026	0.16 TO 2.5	0.0056 TO 0.089	0.26	0.028
HO	< 0.40	0.042	< 0.0089	< 0.0085	0.042 TO 0.42	0.0015 TO 0.015	0.043	0.0046
DY	1.4	0.31	< 0.016	< 0.015	1.7	0.061	0.63	0.067
TB	< 0.27	0.028	< 0.0042	< 0.0040	0.028 TO 0.28	0.0010 TO 0.0099	0.020	0.0022
GD	< 1.4	0.17	< 0.015	< 0.015	0.17 TO 1.4	0.0062 TO 0.050	0.12	0.013
EU	< 0.91	0.11	< 0.0070	< 0.0067	0.11 TO 0.99	0.0039 TO 0.035	0.15	0.016
SM	1.5	1.0	< 0.027	< 0.026	2.5	0.087	0.49	0.053
ND	4.7	3.6	< 0.034	< 0.032	8.3	0.29	8.0	0.86
PR	1.1	0.84	< 0.0060	< 0.0057	1.9	0.068	0.86	0.092
CE	22.	4.5	0.12	< 0.0077	26.	0.94	9.2	0.99
LA	22.	4.6	< 0.0087	< 0.0083	27.	0.94	2.5	0.27
BA	150.	28.	< 1.4	< 0.011	180.	5.6	21.	2.2
CS	1.9	0.59	< 0.0018	< 0.0015	2.3	0.081	0.40	0.043
I	1.8	0.56	0.13	< 0.022	2.5	0.082	0.078	0.0084
TE	< 1.7	< 0.044	< 0.020	< 0.019	< 1.8	< 0.063	< 0.093	< 0.0100
SB	< 1.2	0.24	< 0.014	< 0.013	0.24 TO 1.2	0.0084 TO 0.044	0.26	0.028
SN	< 1.4	0.28	< 0.29	0.14	0.42 TO 1.7	0.015 TO 0.062	1.2	0.13
CD	< 0.40	0.051	0.035	< 0.023	0.086 TO 0.43	0.0030 TO 0.015	0.43	0.046
PD	< 2.3	< 0.061	< 0.019	< 0.018	< 2.4	< 0.087	< 0.093	< 0.0100

APPENDIX B

B&W/ALLIANCE LEVEL 1 LABORATORY ORGANIC ANALYTIC DATA

COMBUSTOR FLUE GAS ORGANIC MODULE

CH_2Cl_2 Extract, Day 1, BW1-1-01-XM

Extractable Organics:

TCO	=	2970 µg
GRAV	=	20290 µg
TOTAL	=	23260 µg = 885 $\mu g/m^3$

Infrared Analysis:

Compound Classes	Comment
aryl, unsaturated esters	strong
saturated esters	medium
alcohols	possible, weak
substituted aliphatics	strong
substituted aromatics	medium
carboxylic acids	strong

Liquid Chromatography:

No LC separation was performed on this sample because 70 percent of the extract concentrate (7/10mℓ) was required for bioassay.

COMBUSTOR FLUE GAS COARSE (>3 μm) PARTICLES

CH_2Cl_2 Extract, Day 1, BW1-1-01-CC

Extractable Organics:

TCO	=	not analyzed
GRAV	=	< blank
TOTAL	=	< blank

Infrared Analysis:

Compound Classes	Comment
esters	weak
substituted aliphatics	weak

Liquid Chromatography:

Did not meet Level 1 criteria for LC separation.

COMBUSTOR FLUE GAS FINE (<3 μm) PARTICLES

CH_2CL_2 Extract, Day 1, BW1-1-01-FC

Extractable Organics:

TCO	=	not analyzed
GRAV	=	727 μg
TOTAL	=	727 μg = 28 $\mu g/m^3$

Infrared Analysis:

Compound Classes	Comment
carbonyl compounds (general)	possible (weak)
substituted aliphatics	medium
substituted aromatics	possible (weak)

Liquid Chromatography:

Did not meet Level 1 criteria for LC separation.

COMBUSTOR FLUE GAS COMPOSITE SAMPLE

CH_2Cl_2 Extract, Day 1, BW1-1-01-CD-LE

Extractable Organics:

TCO	=	4 µg
GRAV	=	684 µg
TOTAL	=	688 µg = 26 $\mu g/m^3$

Infrared Analysis:

Compound Classes	Comment
substituted aliphatics	weak
aryl or unsaturated ethers	weak

Liquid Chromatography:

Did not meet Level 1 criteria for LC separation.

COMBUSTOR CYCLONE CATCH

CH_2Cl_2 Extract, Day 1, BW1-1-03-CP

Extractable Organics:

TCO	=
GRAV	=
TOTAL	=

Infrared Analysis:

Compound Classes	Comment
aliphatic hydrocarbons	weak
aryl or unsaturated esters	weak

Liquid Chromatography:

Did not meet Level 1 criteria for LC separation.

SPENT COMBUSTION BED MATERIAL

CH_2Cl_2 Extract, Day 1, BW1-1-04-CB

Extractable Organics:

TCO	=
GRAV	=
TOTAL	=

Infrared Analysis:

Compound Classes	Comment
aliphatic hydrocarbons	strong

Liquid Chromatography:

Did not meet Level 1 criteria for LC separation.

COAL FEED

$CH_2C\ell_2$ Extract, Day 1, BW1-1-05-CF

Extractable Organics:

TCO	=	70,000 µg
GRAV	=	233,000 µg
TOTAL	=	303,000 µg = 3030 g/g

Infrared Analysis:

Compound Classes	Comment
ketones	possible (weak)
alcohols	possible (medium)
substituted aliphatics	strong
substituted aromatics	strong
N-heterocyclics	medium
amines	medium

Very complex IR!

Liquid Chromatography:

Fraction No.	TCO,[b] mg			GRAV,[b] mg			Total (mg)	Fraction distri- (%)	Emissions
	Total	Blank	Corrected	Total	Blank	Corrected			
1	2.61	0.214	2.40	37.88	0.1180	37.76	40.2	15	0.402
2	3.12	ND	3.12	2.0900	LB	2.0900	5.21	1.9	0.0521
3	43.5	0.109	43.4	77.95	0.0314	77.92	121	44	1.21
4	0.583	ND	0.583	23.20	0.0514	23.15	23.7	8.7	0.237
5	N.O.	ND	ND	14.15	0.106	14.04	14.0	5.1	0.140
6	0.706	0.000268	0.706	51.90	LB	51.90	52.6	19	0.526
7	N.O.	ND	ND	19.00	3.386	15.61	15.6	5.7	0.156
	50.5	0.323	50.2	226.2	3.693	222.5	272	99	2.72

ND = No data.

[a]Total mg ÷ 100 gm extracted.

[b]Total mg, LCB- and aliquot-corrected.

[c]Quantity in portion placed on column, actual mg.

[d]Quality recovered from column, actual mg (LCB-corrected).

[e]Percent recovery (mg recovered ÷ mg placed on column.

LC COLUMN RECOVERY

	TCO (mg)	GRAV (mg)	Total (mg)
Taken for LC[c]	14.0	47.50	61.5
Recovered[d]	10.1	45.23	55.3 (90%)[e]

COMBUSTOR FLUE GAS ORGANIC MODULE

CH_2Cl_2 Extract, Day 2, BW1-2-01-XM

Extractable Organics:

TCO	=	3390 µg
GRAV	=	13210 µg
TOTAL	=	16600 µg = 588 µg/m^3

Infrared Analysis:

Compound Classes	Comment
aryl or unsaturated esters	medium
ketones	possible
substituted aliphatics	medium
substituted aromatics	medium
carboxylic acids	medium

Liquid Chromatography:

Fraction No.	TCO,[b] mg			GRAV,[b] mg			Total (mg)	Fraction distribution (%)	Emissions,[a] (mg/m^3)	> 0.5 mg/m LRMS
	Total	Blank	Corrected	Total	Blank	Corrected				
1	0.0430	0.0209	0.0221	1.728	0.04300	1.685	1.707	16	0.0605	No
2	0.0277	0.00298	0.0247	0.09110	0.05140	0.0347	0.0644	0.6	0.00228	No
3	0.0502	ND	0.0502	0.2500	0.06000	0.1900	0.240	2.3	0.00850	No
4	ND	ND	ND	0.3960	0.1030	0.2930	0.293	2.8	0.0103	No
5	0.0346	ND	0.0346	0.5700	0.0857	0.4843	0.519	4.9	0.0184	No
6	0.424	0.0147	0.409	3.203	0.07430	3.129	3.538	33	0.125	No
7	0.125	ND	0.125	5.013	0.9290	4.084	4.209	40	0.149	No
Sum	0.705	0.0386	0.666	11.25	1.346	9.905	10.57	100	0.374	

[a] Total mg ÷ volume of air sampled: 28.23 dscm.

[b] Total mg, LCB- and aliquot-corrected.

[c] Quantity in portion placed on column, actual mg.

[d] Quantity recovered from column, actual mg (LCB-corrected).

[e] Percent recovery (mg recovered ÷ mg placed on column.

LC COLUMN RECOVERY

	TCO, mg	GRAV, mg	Total, mg
Taken for LC[c]	2.784	11.34	14.134
Recovered[d]	0.541	8.649	9.190 (65%)[e]

Infrared Analysis of LC Fractions:

Fraction	Compound Classes	Comment
LC1	aliphatic hydrocarbons	weak
LC2	aliphatic hydrocarbons	trace
	aryl or unsaturated esters	trace
LC3	aryl or unsaturated esters	weak
	substituted aliphatics	weak
	substituted aromatics	trace
LC4	aryl or unsaturated esters	weak
	substituted aliphatics	weak
	substituted aromatics	trace
LC5	aryl or unsaturated esters	weak
	substituted aliphatics	weak
	substituted aromatics	trace
LC6	aryl or unsaturated esters	medium
	saturated esters	weak
	ketones	possible
	substituted aliphatics	medium
	substituted aromatics	medium
	carboxylic acids	medium
	Very complex IR!	
LC7	aryl or unsaturated esters	medium
	saturated esters	weak
	ketones	possible
	substituted aliphatics	medium
	substituted aromatics	medium
	carboxylic acids	medium
	Very complex IR!	

COMBUSTOR FLUE GAS COARSE (>3 μm) PARTICLES

CH_2Cl_2 Extract, Day 2, BW1-2-01-CC

Extractable Organics:

TCO	=	not analyzed
GRAV	=	< blank
TOTAL	=	< blank

Infrared Analysis:

Compound Classes	Comment
esters	trace
substituted aliphatics	weak

Liquid Chromatography:

Did not meet Level 1 criteria for LC separation.

COMBUSTOR FLUE GAS FINE (<3 μm) PARTICLES

CH_2Cl_2 Extract, Day 2, BW1-2-01-FC

Extractable Organics:

TCO	=	not analyzed
GRAV	=	852 μg
TOTAL	=	852 μg = 30 $\mu g/m^3$

Infrared Analysis:

Compound Classes	Comment
esters	trace
ketones	possible
substituted aliphatics	weak

Liquid Chromatography:

Did not meet Level 1 criteria for LC separation.

COMBUSTOR FLUE GAS COMPOSITE SAMPLE

CH_2Cl_2 Extract, Day 2, BW1-2-01-CD-LE

Extractable Organics:

TCO	=	4 µg
GRAV	=	622 µg
TOTAL	=	626 µg = 22 $\mu g/m^3$

Infrared Analysis:

Compound Classes	Comment
esters	weak

Liquid Chromatography:

Did not meet Level 1 criteria for LC separation.

COMBUSTOR CYCLONE CATCH

CH_2Cl_2 Extract, Day 2, BW1-2-03-CP

Extractable Organics:

TCO	=	458 µg
GRAV	=	350 µg
TOTAL	=	808 µg = 1.6 µg/g

Infrared Analysis:

Compound Classes	Comment
esters	weak
substituted aliphatics	weak

Liquid Chromatography:

Did not meet Level 1 criteria for LC separation.

SPENT COMBUSTION BED MATERIAL

CH_2Cl_2 Extract, Day 2, BW1-2-04-CB

Extractable Organics:

TCO	=	13 µg
GRAV	=	5290 µg
TOTAL	=	5303 µg = 7.6 µg/g

Infrared Analysis:

Compound Classes	Comment
aliphatic hydrocarbons	medium
aryl or unsaturated esters	weak

Liquid Chromatography:

Did not meet Level 1 criteria for LC separation.

COAL FEED

CH_2Cl_2 Extract, Day 2, BW1-2-05-CF

Extractable Organics:

TCO	=	48000 µg
GRAV	=	188000 µg
TOTAL	=	236000 µg = 2360 µg/g

Infrared Analysis:

Compound Classes	Comment
ketones	possible (weak)
alcohols	possible (medium)
substituted aliphatics	strong
substituted aromatics	strong
n-heterocyclics	possible (medium)
amines	medium

Liquid Chromatography:

Fraction No.	TCO,[c] mg			GRAV,[c] mg			Total, mg	Fraction Distribution,%	Emissions,[b]
	Total	Blank	Corrected	Total	Blank	Corrected			
1	12.200	0.214	12.000	37.300	0.1180	37.180	49.20	22.0%	0.492
2	4.180	ND	4.180	1.736	LB	1.736	5.92	2.7%	0.059
3	34.800	0.109	34.600	52.360	0.0314	52.330	86.90	39.0%	0.869
4	0.396	ND	0.396	18.600	0.0514	18.550	18.90	8.5%	0.189
5	0.334	ND	0.334	10.680	0.1060	10.570	10.90	4.9%	0.109
6	1.750	0.268	1.750	34.080	LB	34.080	35.80	16.0%	0.358
7	1.190	ND	1.190	16.680	3.3860	13.290	14.50	6.5%	0.145
Sum	58.000	0.600	57.400	171.400	3.6930	167.700	222.00	100.0%	

[a] Quantity in entire sample, blank- and aliquot-corrected.

[b] Total mg ÷ 100 gm extracted.

[c] Total mg, LCB- and aliquot-corrected.

[d] Quantity in portion placed on column, actual mg.

[e] Quantity recovered from column, actual mg (LCB-corrected).

[f] Percent recovery (mg recovered ÷ mg placed on column.

LC column recovery			
	TCO, mg	GRAV, mg	Total, mg
Taken for LC[d]	12.0	48.23	60.2
Recovered[e]	13.7	42.86	56.6 (94%)[f]

END

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